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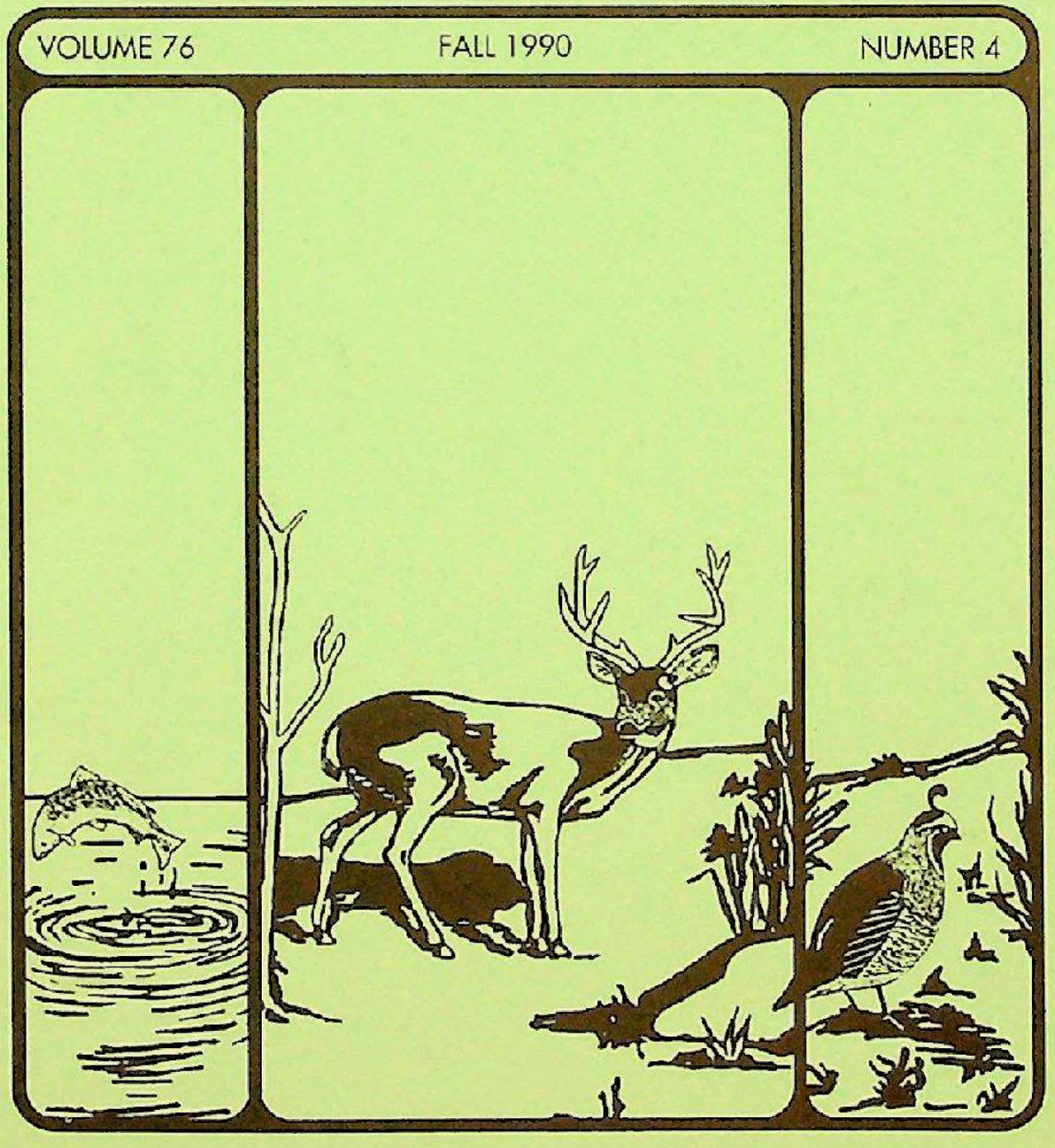

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## CHANGE OF EDITORSHIP

With this issue, Eric R. Loft, Associate Wildlife Biologist with the Wildlife Management Division, assumes the duties of Editor-in-Chief of California Fish and Game.

Dr. Loft's assumption of the editorship follows the Department's policy of rotating the editorship between staff members representing Marine Resources, Inland Fisheries, Wildlife Management, and the Bay-Delta Project.

Under his guidance, the Journal will continue its policy of presenting to the public the results of scientific investigations as they relate to management programs and the conservation of California fish and wildlife resources. Dr. Loft will strive to maintain and enhance the excellent reputation the Journal has gained over the last 76 years.

Dr. Loft will be ably assisted in his duties by associate editors: Betsy Bolster, L.B. Boydstun, and Chuck Knutson, Inland Fisheries; Don Stevens, Bay-Delta Project; Dan Yparraguirre, Kent Smith, and Doug Updike, Wildlife Management; Pete Phillips, Environmental Services; and Doyle Hanan and Jerry Spratt, Marine Resources.

To Dr. Robert Lea, Editor-in-Chief of the past 4 years, we wish to express our appreciation for a job well done. Dr. Lea guided the Journal through its 75th anniversary year, a milestone and record for any continuously published journal in California. *Pete Bontadelli, Director, California Department of Fish and Game.*

CALIFORNIA FISH AND GAME

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# RESPONSES OF MOUNTAIN SHEEP TO HELICOPTER SURVEYS[1]

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**Effects of helicopter surveys on distribution and movements of desert-dwelling mountain sheep, *Ovis canadensis*, were studied in San Bernardino County, California during April and June 1988. Adult males and females with radio collars moved about 2.5 times farther the day following a helicopter survey than on the previous day. Further, 35-52% of these animals changed polygons (8-83 km$^2$) following sampling from a helicopter, whereas only 11% did so on the day prior to the survey. Likewise, some animals left the study area following surveys. Sampling intensity (0.8 min/km$^2$ vs. 2.0 min/km$^2$) had little effect on movement of mountain sheep. Similarly, terrain type (steep vs. rolling) did not influence movement of female mountain sheep following helicopter surveys. Movement by mountain sheep during a helicopter survey may violate fundamental assumptions of several population estimators.**

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## INTRODUCTION

Helicopters are used for numerous wildlife management and research purposes (Thompson and Baker 1981, Bleich 1983*a*), and the potential for aircraft to alter wildlife behavior has been known for many years (Petrides 1953, Grzimek and Grzimek 1960, Siniff and Skoog 1964, and others). Geist (1971) and Klein (1972, 1973) cautioned that wildlife may respond negatively to aircraft, but only recently have studies of such responses been undertaken (Calef et al. 1976, MacArthur et al. 1979, Miller and Gunn 1979, 1980, Davis et al. 1983, Gunn et al. 1983, Krausman and Hervert 1983, Valkenburg and Davis 1983, Krausman et al. 1986, Miller et al. 1988). To date, only Calef et al. (1976), Miller and Gunn (1979, 1980), Gunn et al. (1983), and Miller et al. (1988) have detailed the effects of helicopters on wildlife.

Krausman and Hervert (1983) reported that 41% of 32 mountain sheep, *Ovis canadensis*, were disturbed by fixed-wing aircraft and >19% changed habitats as a result of that disturbance. Thus, we tested whether low-flying helicopters also would disturb mountain sheep. We hypothesized that individual mountain sheep: (i) would move further the 'day' immediately following the helicopter survey than the 'day' immediately preceding such sampling; (ii) would change sampling polygons following a helicopter survey; (iii) should respond differently to helicopter surveys, depending upon the type of terrain in which they were located (V. Geist, Unpubl. Rep. to the Berger Commission, Univ. Calgary 1975); and (iv) would exhibit a greater response to high than low intensity sampling.

## METHODS

This research was conducted at Old Dad Peak and the Kelso Mountains, San Bernardino County, California (Lat. 115 degrees, 50 min W, Long. 35 degrees, 06 min N). The study area is located in the Mohave Desert; two vegetative types, the creosote bush, *Larrea tridentata*, and Joshua tree, *Yucca brevifolia*, series predominate (Paysen et al. 1980). Geologically, the western one-fourth of the 225 km$^2$ study area consists of a series of limestone massifs that are extremely steep with slopes normally >100% (hereafter referred to as steep). To the east the area is dominated by a series of rolling hills of primarily granitic origin with slopes generally <100% (hereafter referred to as rolling). The study area was divided into nine polygons inhabited by sheep, ranging in size from 8 - 83 km$^2$ ($\bar{x}$ = 25.8 km$^2$, SD = 22.5 km$^2$). Polygons were delimited by roads and natural breaks in topography. At least 200 mountain sheep occurred in the study area (Bleich 1983*b*).

Thirty mountain sheep (15 male, 15 female) were captured using drive-nets (Beasom et al. 1980) or a net-gun fired from a helicopter (Krausman et al. 1985) and were fitted with radio-telemetry collars (Telonics, Mesa, AZ). These animals were located weekly from a fixed-winged aircraft (Cessna 185) in the manner described by Krausman et al. (1984). Responses of mountain sheep to the presence of a low-flying helicopter were evaluated on two occasions (April and June 1988). Mountain sheep with radio collars were located from the airplane

the morning prior to the day of the helicopter survey (T1), the morning of (but before) the helicopter survey (T2), and the morning immediately following the morning helicopter survey (T4). In April, animals also were relocated in the afternoon (T3) immediately following the morning helicopter survey. These telemetry locations (error $\leq$ 4 ha; Krausman et al. 1984) were plotted on 15 min USGS topographic maps; error was small relative to the size of polygons.

Demographic surveys were conducted by three experienced observers and an experienced pilot using a Bell 206B-III turbine-powered helicopter. Such surveys began immediately after the fixed-wing aircraft exited the study area (0730 PST), and the crew had no knowledge of the locations of radio-collared animals. We varied survey intensity between April (0.81 min/km$^2$) and June (2.03 min/km$^2$). We flew low-level contours similar to normal surveys of mountain sheep in this area. Because of high topographic diversity, both vertical and lateral distances from the ground varied considerably (50-200 m) but were similar for April and June. Observers recorded mountain sheep locations on 15 min USGS topographic maps, as well as sex and age class of sheep, and topography of terrain.

Effects of helicopter surveys on mountain sheep were analyzed by comparing straight-line distances between locations of radio-collared animals before and after the survey (Wilcoxon Matched-Pairs Signed-Ranks Test, Siegel 1956). These relocations served as an index to distances moved by mountain sheep. Changes in distribution among polygons before and after the survey and under low and high survey intensity were compared with the *Z*-test for proportions (Zar 1984). Relationship between the size of polygon and proportion of sheep leaving a polygon was tested with a Spearman rank correlation (Siegel 1956). Differences in distances moved by females before and after helicopter sampling, as a function of terrain type, were tested using the Mann-Whitney *U*- test (Siegel 1956).

## RESULTS

Distances between relocations of male mountain sheep during the 24-hour period prior to the helicopter survey (T1-T2) were less than distances moved

**Table 1. Movements of adult male and female mountain sheep before and after helicopter surveys, San Bernardino Co., California, 1988.**

| | Distances moved (km)[a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Before | | | | After | | | |
| | *n* | $\bar{x}$ | SD | Range | *n* | $\bar{x}$ | SD | Range |
| Males | | | | | | | | |
| April | 12 | 1.7 | 0.8 | 0.9-3.8 | 12 | 6.4 | 2.9 | 2.2-12.0 |
| June | 13 | 1.1 | 0.8 | 0.2-2.4 | 13 | 3.3 | 2.0 | 1.0-8.1 |
| Females | | | | | | | | |
| April | 14 | 1.4 | 1.4 | 0.3-5.5 | 14 | 2.3 | 1.8 | 0.3-7.1 |
| June | 14 | 1.6 | 1.0 | 0.3-3.6 | 14 | 2.9 | 2.2 | 0.5-9.9 |

[a] Sampling intensity varied between April and June; see text for explanation.

**Table 2. Percent of mountain sheep that moved among sampling polygons before and after helicopter surveys, San Bernardino Co., California, 1988[a].**

| Sampling interval | | April | | June | |
|---|---|---|---|---|---|
| | | *n* | % moved | *n* | % moved |
| Before | (T1-T2) | 26 | 11.5 | 27 | 11.1 |
| After | | | | | |
| Same Day | (T2-T3) | 26 | 34.6 | - | - |
| Next Day | (T2-T4) | 26 | 38.5 | 27 | 51.9 |

[a]Sampling intensity varied between April and June; see text for explanation.

between the morning of the helicopter survey and the following morning (T2-T4) for both April ($T = 1$, $P < 0.01$) and June ($T = 3$, $P < 0.01$) (Table 1). Differences in distances moved also occurred for females during June ($T = 5$, $P < 0.01$), but not April ($T = 32$, $P < 0.10$), although that difference was marginally nonsignificant.

Proportion of animals that moved to a different sampling polygon after the helicopter survey (T2-T4) was greater than the number that changed polygons during the preceding 24-hour period (T1-T2) for both April ($Z = 2.37$, $P < 0.02$) and June ($Z = 3.59$, $P < 0.001$) (Table 2). During the afternoon in April (T2-T3) the proportion of animals moving among polygons also differed from the morning sample (T1-T2) ($Z = 2.06$, $P < 0.05$; Table 2). Proportions of males (5 of 12) and females (5 of 14) changing polygons did not differ in April ($Z = 0.313$, $P > 0.70$) or June (7 of 13 males, 7 of 14 females; $Z = 0.305$, $P > 0.70$).

No correlation existed between the size of a polygon and proportion of telemetered mountain sheep moving from it following helicopter surveys (T2-T4) (April and June combined; $r_s = 0.16$, 11 df, $P > 0.50$). During April, 9 of 26 telemetered animals changed sampling polygons within 6 hours of the beginning of the helicopter survey (T2-T3), and 10 of 26 changed polygons overnight (T2-T4). During June, 14 of 27 animals changed sampling polygons the day following the helicopter survey (T2-T4). Four (all males) of 26 sheep completely left the study area in April, whereas none of 27 animals did so during June.

Survey intensity was 2.5 times greater in June than in April, and a larger proportion of mountain sheep moved to a different sampling polygon in June (Table 2). This difference, however, was not significant ($Z = 0.989$, $P > 0.30$). Likewise, a Mann-Whitney *U*-test showed no significant differences between distances moved by female sheep inhabiting steep or rolling terrain (Table 3) in either April ($Z = 0.495$, $P > 0.60$) or June ($Z = 0.452$, $P > 0.65$).

## DISCUSSION

Caughley (1974) and Caughley et al. (1976) reviewed potential biases of estimates obtained from aerial sampling of large mammals; accuracy declined with increasing width of transect, cruising speed, and altitude. Further, several researchers recognized the potential for aircraft to alter the behavior of animals

**Table 3. Change in distance moved (distance moved after helicopter survey minus distance moved before survey) by type of terrain by female mountain sheep, San Bernardino County, California, 1988.**

| | Change in distance moved (km)[a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | April | | | | June | | | |
| Terrain | *n* | $\bar{x}$ | SD | Range | *n* | $\bar{x}$ | SD | Range |
| Steep | 10 | 1.1 | 2.1 | -1.7 - 5.3 | 6 | 1.9 | 3.5 | -0.9 - 9.4 |
| Rolling | 4 | 0.3 | 3.1 | -4.2 - 4.3 | 8 | 0.9 | 0.5 | 0 - 1.8 |

[a]A negative value under range results from an animal having moved a lesser distance after than before the helicopter survey. Sampling intensity varied between April and June; see text for explanation.

and thereby influence survey results (Petrides 1953, Gilbert and Grieb 1957, Grzimek and Grzimek 1960, Bergerud 1963, Siniff and Skoog 1964, and others). Only recently, however, have investigators begun to evaluate this potential bias, and much of this effort has focused on the effects of fixed-wing aircraft on telemetered animals (Krausman and Hervert 1983, Krausman et al. 1986).

With the exceptions of Gunn et al. (1983) and Beasom et al. (1986), effects of helicopters on the distribution or sightability of wildlife has not been evaluated. Beasom et al. (1986) determined that intensive helicopter sampling resulted in multiple sightings of individual white-tailed deer, *Odocoileus virginianus*, but concluded only that duplication may serve to render total counts less conservative. Gunn et al. (1983) observed that helicopter overflights, followed by landings up to 2 km from post-calving aggregations of caribou, *Rangifer tarandus*, elicited behavioral responses leading to displacements of at least 1-3 km. We documented that helicopter censusing had a substantial effect on movements of mountain sheep.

Mountain sheep altered both distribution and movements in response to helicopter surveys (Tables 1 and 2). Although some data (T4) were obtained 12-14 hours after the completion of the helicopter surveys, we believe that long-distance movements, as well as changes in distribution by sheep with respect to sampling polygons, began at the onset of the helicopter surveys. Many mountain sheep took flight at the approach of the helicopter. Daily point relocations are not the best measure of total distance moved (Bowyer 1981, Laundré et al. 1987), but we suggest such measures provide a reliable index to distance moved. Indeed, Bowyer (1981) reported that point relocations were a conservative measure of daily movements.

Although mountain sheep were disturbed by helicopters, no differences occurred in distances moved by females in steep or rolling terrain (Table 3). These data do not support speculation by Geist (unpubl. rep. to the Berger Commission, Univ. Calgary, 1975) that mountain sheep in escape terrain should respond less strongly to disturbances by aircraft than those in less precipitous terrain, but our sample size is small. Ostensibly, sheep in precipitous

terrain reacted as strongly to the helicopter as those in less rugged areas because of the extreme noise associated with the helicopter (Klein 1972, Kufeld et al. 1980).

No significant difference occurred in distribution of mountain sheep as a result of survey intensity. Even the low survey intensity during April was sufficient to cause major changes in mountain sheep distribution. Again, we postulate that noise associated with helicopter censusing caused considerable disturbance.

The double-sampling technique of Magnusson et al. (1978) has been used to census mountain sheep in California (Holl and Bleich 1983) and Arizona (J. de Vos, pers. comm., Arizona Game and Fish Dept.), even though this procedure requires that the location of sample animals be fixed (Pollock and Kendall 1987). This double-sampling procedure is an extension of the Lincoln-Peterson estimator (Magnusson et al. 1978) and must comply with a number of assumptions to yield reliable information (Rice and Harder 1977:203).

Helicopter surveys of mountain sheep in this study would have resulted in violations of several fundamental assumptions required by most mark-recapture estimators: i) mountain sheep movements resulted in the population not being closed (4 sheep left the study area following the April survey); ii) the probability of "recapturing" an animal was not constant (sheep moved considerable distances, and 35-53% of them changed sampling polygons following the helicopter survey; this only would be important where locations of unmarked animals during the first survey were used to identify them during the second survey — a practice used in both California and Arizona); and (iii) surveys were not independent. Violations of assumptions i and ii would affect the accuracy of the estimate, whereas violation of assumption iii would affect its precision (Rice and Harder 1977).

The potential for overestimating population size in other types of surveys exists (i.e., from double counting animals that changed sampling polygons; Grzimek and Grzimek 1960, Siniff and Skoog 1964, Beasom et al. 1986). This might be mitigated by animals leaving the study area, or by using an estimator that allowed for sampling with replacement (Rice and Harder 1977).

Helicopters have many advantages over fixed-wing aircraft for sampling large animals (Samuel et al. 1987). Further, in some instances helicopters may disturb wildlife less than airplanes (Calef et al. 1976). Additionally, animals moving because of the noise generated by helicopters (Kufeld et al. 1980) might be easier to see than standing or bedding ones (Gasaway et al. 1985, Samuel et al. 1987). Nevertheless, mountain sheep reacted severely to our helicopter surveys, and these reactions may introduce biases into results obtained from similar sampling procedures. We have termed these reactions the "Bo-Peep" effect, because investigators cannot know the precise locations of previously observed animals as the survey progresses. Thus, we caution that the use of helicopters to estimate population size of mountain sheep using the double sampling technique (Magnusson et al. 1978) may be problematical, especially when the first survey is conducted with a helicopter.

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# ACCURACY IN RECORDING NECK-BAND CODES OF CACKLING CANADA GEESE[1]

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**In response to a continuing decline in numbers of cackling Canada geese (*Branta canadensis minima*), a major effort of neck-banding and observing marked geese was begun in 1982 to assess distribution and survival of these geese. Cooperators contributed data from throughout the winter range of cackling geese from Washington to the San Joaquin Valley of California. Problems arose in the correct identification of neck-band codes. The least experienced or "casual" observers made 4.8 times the rate of errors than were made by experienced agency cooperators and 23.2 times the errors of primary project personnel. Training and experience in reading neck-band codes is important to avoid these errors.**

## INTRODUCTION

Numbers of cackling geese censused in the Klamath Basin of California (primarily at Tule Lake National Wildlife Refuge (NWR) (Lat. 41 degrees 56'N, Long. 121 degrees 23'W) declined from about 350,000 in the mid 1960's to about 30,000 in 1983 (Raveling 1984). With the cooperation of the California Department of Fish and Game (CDFG) and the U.S. Fish and Wildlife Service (USFWS), we conducted a study of distribution and survival of these geese from 1982-83 through 1987-88, relying on repeated observations of neck-banded geese. By 1984, we were receiving observations from many cooperators from Washington to central California, including the public. We quickly became aware that several errors were being reported such as neck-band codes that had not been used, codes on birds known to be dead, and several unique sightings of geese not seen by our field crew who observed the geese full-time during the winter. The purpose of this report is to demonstrate the different error rates made by different categories of observers related to the knowledge of codes used and experience in reading neck-bands.

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## METHODS

Between 1982 and 1987, 3,635 cackling geese were neck-banded, both when flightless on the breeding grounds on the Yukon-Kuskokwim Delta, Alaska, and with cannon-nets at Tule Lake and Sacramento NWR's. A small number of cackling geese were fitted with transmitters ($n$=23) or had blood samples taken ($n$=22) by the USFWS and these geese were excluded from analyses. Neck-bands were yellow and inscribed with 3 black alpha-numeric codes or just numeric codes. Neck-bands were 41.28 mm high, 33.84 mm inside diameter, and 1.59 mm thick. Codes were inscribed twice on the neck-band with one horizontal and two vertical letters and numbers (e.g.,:

and so on). This arrangement was used to maximize readability of these small collars. The correct order for recording codes was the horizontal letter or number followed by the vertical letters or numbers read from bottom to top. Because this arrangement of codes wrapped partially around the neck-band, care was needed to be sure an observer clearly saw all figures on the band. Appendix 1 contains codes used to date and problems that occur in reading them. Occasionally the glue used to secure the band on the neck caused some black feathers to adhere to the band and made reading difficult. Care was also needed to read the vertical codes in proper order when a goose had its head and neck down when feeding. Under ideal light conditions, neck-band codes could be identified up to 451 m (500 yds). It was tempting to record a code at distances beyond which resolution was clear, or to "guess" a number or digit even if it was only partially seen, especially if a code had been previously seen regularly at the same location. Experienced observers were aware of the design of the digits used, some of which were stylized (Appendix 1). Relatively inexperienced observers were not very familiar with the codes and the chances for error in reading such codes.

In 1982-83 and 1983-84, nearly all records were made by one University of California, Davis (UCD) graduate student (Johnson 1988) as there were relatively few neck-banded geese and a much less coordinated effort throughout their winter range. From 1984 on there were more persons involved in the study. Here we present results only from 1984-85 through 1987-88.

Single sightings of a goose during an entire winter were highly suspect if the goose had not been seen the previous winter or afterwards. Our resighting rates of geese exceeded 90% [based on an analysis using program RELEASE (unpubl. data) described by Burnham et al. (1987)], lending confidence to our suspicion that single sightings were erroneous.

**Table 1. Proportions of total, unique, and known erroneous records of neck- banded cackling Canada geese in relation to experience and assignment of responsibility of observers.**

| Observer group | Year | No. of observers | Total collars read (as % of all sightings) | No. of single sightings (as % of all single sightings) | No. of known erroneous records (as % of all erroneous records)[a] |
|---|---|---|---|---|---|
| Primary field crew | 1984-85 | 2 | 5,056[b] (67.4%) | 59 (45.0%) | 11 (29.0%) |
| | 1985-86 | 8[c] | 12,086 (83.0%) | 96 (64.9%) | 16 (32.7%) |
| | 1986-87 | 7[d] | 20,496 (84.0%) | 97 (58.8%) | 19 (42.2%) |
| | 1987-88 | 6[e] | 7,202 (81.9%) | 70 (40.9%) | 2 (7.7%) |
| | Subtotals | | 44,840 (82.6%) | 322 (52.4%) | 48 (30.4%) |
| Agency cooperators assigned to assist project part time | 1984-85 | 5+[f] | 1,588 (21.2%) | 41 (31.3%) | 12 (31.6%) |
| | 1985-86 | 7+[f] | 1,647 (11.3%) | 27 (18.2%) | 5 (10.2%) |
| | 1986-87 | 9+[f] | 2,319 (9.9%) | 53 (32.1%) | 6 (13.3%) |
| | 1987-88 | 10+[f] | 913 (10.4%) | 48 (28.1%) | 11 (42.3%) |
| | Subtotals | | 6,467 (11.9%) | 169 (27.5%) | 34 (21.5%) |
| Other agency personnel and private citizens | 1984-85 | 18+[f] | 855 (11.4%) | 31 (23.7%) | 15 (39.5%) |
| | 1985-86 | 58+[f] | 821 (5.6%) | 25 (16.9%) | 28 (57.1%) |
| | 1986-87 | 37+[f] | 623 (2.7%) | 15 (9.1%) | 20 (44.4%) |
| | 1987-88 | 29+[f] | 677 (7.7%) | 53 (31.0%) | 13 (50.0%) |
| | Subtotals | | 2,976 (5.5%) | 124 (20.2%) | 76 (48.1%) |
| Totals | | | 54,283 | 615 | 158 |

[a]Non-existent codes or geese known to be dead.
[b]Of geese banded prior to autumn 1984; from 1985 on, all geese were banded in summer in Alaska.
[c]Three University of California, Davis (UCD) personnel + 4 UCD cooperators + 1 private volunteer.
[d]Two UCD personnel + 4 UCD cooperators + 1 private volunteer.
[e]Two UCD personnel + 2 UCD cooperators + 2 private volunteers.
[f]Some records were received from a refuge or a person that represented contributions from more than one individual, but total number of participants was unspecified.

## RESULTS

We categorized observers based on their affiliation with the project and experience (Table 1). In total, the primary field crew observed 82.6% of the 54,283 observations of neck-banded geese. Neck-bands read more than once a day were recorded only once in Table 1 unless the first observation was unique and the band was read by two or more individuals or in two or more locations.

The error rate in recording neck-bands was related to the experience and degree of relationship of observers to the project. Errors increased as more cooperators contributed data. In total, the least experienced or "casual" observers contributed only 5.5% of all neck-band sightings but 20.2% of unique

**Table 2. The proportion of single sightings of neck-banded cackling Canada geese which had not been seen the previous year used as an error correction factor applied to total number of neck-bands seen during winter.**

| Year | No. of single sightings[a] | No. of those single sightings not seen the previous year | Error |
|---|---|---|---|
| 1983-84 | 40 | 11 | 27.5% |
| 1984-85 | 122 | 79 | 64.8% |
| 1985-86 | 94 | 43 | 45.7% |
| 1986-87 | 119 | 52 | 43.7% |
| 1987-88 | 97 | 38 | 39.2% |

[a]Sightings only of geese banded in previous years.

(single) sightings and 48.1% of known erroneous records. The error rate in reading neck-bands by these least experienced and/or least identified with the project personnel (76 vs 2,976 = 2.55%) was 4.8 times greater than the error rate of experienced assigned agency cooperators (34 vs 6,467 = 0.53%) and 23.2 times greater than that of the primary project personnel (48 vs 44,840 = 0.11%) (Table 1).

Variation in accuracy of recording neck-band codes, especially of codes seen only once during a winter season, presented a dilemma for using the total number of different neck-banded geese seen to estimate population sizes with marked : unmarked ratios and survival rates (to be reported elsewhere). If all single sightings were included, they included some birds that were not alive. If all single sightings were excluded, some birds were excluded that were alive but perhaps in locations where there were relatively fewer observers or observers had difficulty seeing their neck-bands because of distance or access. A value between these two extremes would be closest to the truth.

In practice, the known error rate was small compared to the total number of sightings but potentially large as a proportion of single sightings. To illustrate, the total number of observations of neck-bands between 1984-85 and 1987-88 was 54,283, of which only 615 (1.1%) were of a code seen only once (see Totals in Table 1). However, 158 of these 615 single sightings (25.7%) were of geese known to be dead or non-existent band codes. Thus, the total number of individual neck-banded geese seen in a year contained several records that were likely erroneous.

Data on probable error rates of single sightings are provided in Table 2. No estimate of error could be provided for 1982-83 as this was the first year geese were marked. The numbers of single sightings and error rate were much larger in 1984-85 than in 1983-84 probably because 1984-85 was the first year in which a much greater number of observers participated in the study. Since then, the error rate has gradually decreased, probably as cooperators gained experience.

## DISCUSSION

The error rates in this study should not be generalized to other studies as neck-band codes, materials, distances between geese and observers, and observers' efforts and experience vary. However, study of neck-banded cackling geese has continued under the supervision of the USFWS with help from CDFG, UCD, and other persons. Temporary employees now contribute much of the data. We think field staff should be familiar with the codes used, the stylized nature of some of the numbers, and training to be sure that each digit or number is recognized and seen clearly. Although the number of errors is relatively small, they can be reduced. The alternative would be to utilize only codes read by agency cooperators, but this would eliminate a significant number of observations, especially those from areas with small numbers of cackling geese because effort is usually concentrated where large flocks concentrate.

## ACKNOWLEDGMENTS

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**Appendix 1. Codes used on cackling goose neck-bands and possible sources of error.**

| Code letter or digit | Comments |
|---|---|
| A | Difficult to see cross bar at a distance or with heat waves; may be identified as a I or N depending on angle of observation. |
| C | Can be read as a O if total letter not clear. |
| E | Feathers may obscure top or bottom "leg." |
| H | Can mistake for a 4 if angle or feathers obscure lower left "leg." |
| J | Can be read as a I if bottom hook not seen. |
| K | Usually clear; possible to be read as a I if "arms" of letter obscured |
| L | or as X if straight "arm" not clear. |
| N | Can be read as a I if "leg" not seen. |
| | Has been read as a I or A if not totally seen or feather or heat waves obscure. |
| P | Usually clear. |
| Q | Easily confused with top of 8 or an O. Lower leg (↘) not easily distinguished when geese are in a nonalert posture. |
| T | Crossbar is small and letter can be read as a I. |
| V | Must see clearly as can be confused with Y or K or I. |
| X | Can be read as Y or V if not seen clearly. |
| Y | See comments for V and X. |
| Z | Easily confused with a 2 or 7. |
| 1 | See above comments; easy to "guess" a 1 for any letter with a long axis "leg." |
| 2 | Round on top but still easy to mistake for a Z if top not clearly seen. |
| 3 | Rounded bottom may be read as a 6 or 8, but bottom of 8 is "square" and connection of 6 must be seen. Top "loop" of 3 is narrow and can be easily obscured if heat waves are prevalent. |
| 4 | See comment for H. |
| 5 | Usually clear, although some confusion with E if bottom of 5 not clear. |
| 6 | See above comments for 3. |
| 7 | See above comments for Z and 2. |
| 8 | Can be confused with any letter or number with a loop at bottom which is why bottom part is stylized. |
| 9 | Easily confused with Q. |
| 0 | Clear if totally seen; see comments for C. |

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# FALL AND WINTER FOOD HABITS OF AMERICAN COOTS IN THE NORTHERN SACRAMENTO VALLEY, CALIFORNIA[1]

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**Fall and winter food habits of 100 American coots, *Fulica americana*, were investigated at the Gray Lodge Wildlife Management Area (WMA) during November 1980 through February 1981. Pooled gizzard, esophageal, and proventricular contents were sorted, identified, oven-dried, and weighed. Plant materials constituted more than 99 percent of the total dry weight sample, while animal matter accounted for less than 1 percent. Important plants with percent of total dry weight include *Cynodon dactylon* (45.1%), *Polygonum* sp. (24.7%), *Scirpus acutus* (3.8%), and *Eleocharis* sp. (3.6%). Food habit differences between males and females were non-significant ($P > 0.05$).**

## INTRODUCTION

The food habits of the American coot, *Fulica americana*, have been described in several studies throughout North America (Munro 1939, Jones 1940, Eley and Harris 1976, Fitzner and Schreckhise 1979, Fitzner et al. 1980, and Ivey 1987). In addition, food habits data have been reported incidentally by Harris (1954), Sooter (1954), Batulis and Bongiorno (1972), Burger (1973), and Anderson (1974). Nevertheless, there is a paucity of food habits data in the literature for coots wintering in the Sacramento Valley, California.

The primary objective of this study was to obtain fall and winter food habits data for a northern Sacramento Valley population of American coots. This paper presents findings based on pooled gizzard, esophageal, and proventricular contents from 100 coots collected at the Gray Lodge WMA.

## STUDY AREA

The 3,036 ha Gray Lodge WMA is located approximately 13 km southwest of Gridley, Butte County, California. The facility is administered by the California Department of Fish and Game to provide critical wetland habitat and forage crops for wintering waterfowl and other wetland species. Areas such as Gray Lodge also help reduce potential crop depredation on nearby agricultural lands.

Wetland habitats at Gray Lodge are comprised of permanent and seasonally flooded ponds in association with large stands of hardstem bulrush, *Scirpus*

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*acutus*. Upland habitats provide an assemblage of forage and cover species such as Bermuda grass, *Cynodon dactylon*, blackberry, *Rubus* sp., dock, *Rumex* sp., saltgrass, *Distichlis spicata*, and many other low growing herbaceous species. Many of these species as well as several species of smartweed, *Polygonum* sp., also occur on lowland and levee habitats at Gray Lodge.

## METHODS

A reference collection of plant materials from Gray Lodge was prepared prior to the onset of this investigation. All plants were identified using keys by Beetle (1943), Mason (1957), and Yocom (1951).

All 100 coots were collected during seven outings from seasonally flooded ponds at Gray Lodge. Collection dates and number of coots collected (in parentheses) were: 5 November 1980 (15); 12 November 1980 (10); 19 November 1980 (5); 7 December 1980 (30); 21 December 1980 (11); 7 January 1981 (14); and 14 February 1981 (15). All coots were shot using a 12-gauge shotgun. Having an assistant flush sitting or swimming coots towards a hidden collector proved to be the most effective method of collection. All coots were collected between 1130 and 1400 hours in order to obtain birds at approximately the same stage of their daily foraging cycle.

Coots were sexed internally, examining for the presence of testes or ovaries, while aging of each bird was accomplished using tarsal coloration as the sole criterion (Gullion 1952, Crawford 1978).

The contents of the gizzard, esophagus, and proventriculus from each coot were pooled, then packaged and frozen for later analysis. After thawing, each sample was placed in a porcelain pan and covered with distilled water. Food items were then sorted and identified using identification keys by Beetle (1943), Yocom (1951), Mason (1957), and Pennak (1978). The reference collection and the herbarium at California State University, Chico were also used for plant identification. Once identified, food items were oven-dried for 12 hours at 100 degrees F, and weighed to the nearest 0.001 gram using an analytical balance. Weight measurements were rounded to the nearest 0.01 gram, while values for percent of total dry weight were rounded to the nearest 0.1 percent.

One-Way Analysis of Variance was used to test for food habit differences between the sexes. In order to eliminate relatively unimportant food items, tests were run only for those items occurring in five or more coots. The Chi-square Goodness of Fit Test was used to test for differences between the observed sex ratio from this study and an expected 1:1 ratio of male to female coots.

No attempt was made during this study to test for food habit differences between the various age classes of American coots.

## RESULTS AND DISCUSSION

Plant materials constituted 99.8% of the pooled gizzard, esophageal, and proventricular sample by weight, while animal matter accounted for 0.1% (Table 1). These figures are consistent with other similar studies (those based on gizzard contents alone or pooled gizzard, esophageal, and proventricular contents) which show animal matter comprising from 0 to 2.6% of the total food volumes (Munro 1939, Eley and Harris 1976, Fitzner et al. 1980). In contrast,

**Table 1. Fall and winter foods of 100 American coots collected from November 1980 through February 1981 at Gray Lodge Wildlife Management Area, Butte County, California.**

| Food items | % occurrence | Dry weight (g) | % of total dry weight |
|---|---|---|---|
| Plant foods | | | |
| Chlorophyta | 6 | 0.83 | 2.8 |
| Anthophyta | | | |
| Potamogetonaceae | | | |
| *Potamogeton pectinatus* | 2 | 0.05 | 0.2 |
| Gramineae | | | |
| *Cynodon dactylon* | 78 | 13.18 | 45.1 |
| *Distichlis spicata* | 1 | 0.01 | 0.0 |
| *Echinochloa crusgalli* | 1 | 0.05 | 0.2 |
| *Paspalum distichum* | 2 | 0.01 | 0.0 |
| Cyperaceae | | | |
| *Eleocharis* sp. | 33 | 1.06 | 3.6 |
| *Scirpus acutus* | 26 | 1.12 | 3.8 |
| Juncaceae | | | |
| *Juncus* sp. | 1 | 0.03 | 0.1 |
| Polygonaceae | | | |
| *Polygonum aviculare* | 4 | 0.02 | 0.1 |
| *Polygonum coccineum* | 3 | 0.01 | 0.0 |
| *Polygonum lapathifolium* | 34 | 5.84 | 20.0 |
| *Polygonum persicaria* | 17 | 0.20 | 0.7 |
| *Polygonum* sp. | 6 | 1.13 | 3.9 |
| *Rumex* sp. | 12 | 0.39 | 1.3 |
| Chenopodiaceae | | | |
| *Atriplex* sp. | 2 | 0.01 | 0.0 |
| Unidentified Plant Matter | 79 | 5.28 | 18.0 |
| Total plant material | | 29.22 | 99.8 |
| Animal foods | | | |
| Gastropoda | 2 | 0.01 | 0.0 |
| Isopoda | 1 | 0.01 | 0.0 |
| Insecta | | | |
| Coleoptera | 3 | 0.02 | 0.01 |
| Dermaptera | 1 | 0.01 | 0.0 |
| Odonata | 1 | 0.01 | 0.0 |
| Total animal material | | 0.06 | 0.1 |
| Total | | 29.28 | 99.9 |

Ivey (1987) found that animal matter accounted for 9.8% of his esophageal sample taken from coots collected in the northern San Joaquin Valley, California. His data support findings that gizzard contents alone may overlook readily digestible food items such as soft-bodied invertebrates, and may inflate the importance of seeds and vegetative plant materials due to the digestion rate differential of hard and soft forage items (Bartonek and Hickey 1969, Dirschel 1969, Swanson and Bartonek 1970).

Vegetative plant matter comprised a much greater proportion of the total dry weight sample than did seeds, although seeds were found in the stomach contents of all 100 coots. Important forage items with percent occurrence were: Bermuda grass (78%), willow weed, *Polygonum lapathifolium*, (34%), spike rush (33%), and hardstem bulrush (26%). Other less important items include lady's thumb, *Polygonum persicaria*, (17%) and dock (12%).

Ivey (1987) reported that filamentous green algae, Chlorophyta, accounted for 28.5% of the total aggregate volume of his sample, and was consumed by 56.1% of his 41 coots. In contrast, data from this study indicate that filamentous green algae constituted only 2.8% of the total dry weight and occurred in only 6% of the coots collected. Data from these and other similar studies indicated that filamentous green algae constituted between 0 and 22.2% of the total samples (Munro 1939, Jones 1940, Eley and Harris 1976).

In addition, 5.3 grams of unidentifiable plant material were collected from the 100 bird sample (Table 1). Unidentifiable plant matter as defined by Yocom (1951) 'consists of small ground plant parts such as seeds and leaves etc., that were so fine that identification and sorting was impossible.'

Also, an average of 6.2 grams of grit or fine gravels were found in gizzards. This grit material helps coots break down ingested food items.

Fall and winter food habit differences between male and female coots were nonsignificant ($P > 0.05$). This concurs with results of Eley and Harris (1976) who found no significant sex or age selectivity for specific food items in a fall and winter study along the lower Colorado River. However, Ivey (1987) reported that 'males consumed more vegetative vascular plant parts than females, while females consumed more animal material than males' at the Los Banos Wildlife Area in the San Joaquin Valley.

Fifty-four of the coots collected were female and 46 were male. This difference was not significant from the expected 50:50 ratio ($P > 0.05$).

Coot age classes (number of birds in parentheses) were: birds of the year (27); yearlings (47); and third winter (26). The determination of tarsal coloration is highly subjective among researchers. Crawford (1978) suggested the use of standardized color charts in order to help reduce subjectivity, but this alone does not solve the problem of chronological variation in the deposition of tarsal color pigmentation within a given population. Gullion (1952) found that the appearance of yearling coloration (yellow-green) may appear as early as February in the tarsi of young of the year. This raises a question regarding the use of tarsal coloration as the sole criterion for age determination. Therefore,

I chose not to test for age specific variation in food habits based on data collected using this technique.

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# GENETIC ISOLATION OF STEELHEAD RAINBOW TROUT IN KAISER AND REDWOOD CREEKS, CALIFORNIA[1]

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**The construction of Chabot Reservoir, Contra Costa County, California, in 1875, and the Upper San Leandro Reservoir in 1926, effectively blocked the ocean migration of steelhead trout, *Oncorhynchus mykiss*, in San Leandro Creek. Therefore, *O. mykiss* currently inhabiting the watershed have been genetically isolated from ocean migrating steelhead for over 100 years. We sampled 105 trout in 1984 and 1986 from Redwood and Kaiser creeks, tributaries to the Upper San Leandro Reservoir. Electrophoretically determined genetic profiles of Redwood and Kaiser Creek trout were compared with profiles for other rainbow trout from throughout California. Redwood Creek and Kaiser Creek trout represented unique populations of non-hybridized coastal rainbow trout. Their genetic profile strongly supports the contention that they are descendants of native California steelhead. In addition, Dr. G. W. Gibbons described a distinct species of trout, *Salmo irideus*, from examination of three specimens collected from San Leandro Creek in 1855. This land-locked coastal steelhead trout population is a scientifically valuable and unique natural resource and management plans should be developed to protect them.**

## INTRODUCTION

The construction of Chabot Dam in 1875 effectively isolated trout migration to the ocean via San Leandro Creek, Contra Costa County (Fig. 1). The upstream construction of Upper San Leandro (USL) Dam in 1926 further isolated these trout on protected watershed lands not open to the general public. Major tributaries flowing into USL Reservoir include Redwood Creek, San Leandro Creek, Moraga Creek, and Kaiser Creek (Fig. 1). G. W. Gibbons collected three

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FIGURE 1. Study area illustrating Lake Chabot formed by Chabot Dam, upper San Leandro Reservoir, and Kaiser and Redwood creeks.

trout specimens from San Leandro Creek in 1855 and described the distinct species, *Salmo irideus* (Shapovalov et al. 1959).

According to East Bay Municipal Utility District and East Bay Regional Park District biologists (pers. commun.), adult trout migrate out of the USL Reservoir from January through April to spawn in the tributaries. After hatching (February through May), the young spend one or two years in the creeks before returning to the reservoir during the fall run-off period. This behavior strongly suggests that these fish are descendants of anadramous steelhead trapped first behind Chabot Dam and later behind USL Dam. Also, examination of planting records did not provide any evidence that USL Reservoir had ever been planted with hatchery rainbow trout.

The objective of this study was to ascertain whether these trout populations actually represented native California steelhead. The genetic profiles of USL Reservoir trout were compared with genetic profiles of other California populations of rainbow and steelhead trout.

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## METHODS

Fifty-three yearling trout were collected from Redwood Creek in October 1984, and 52 yearling trout were collected from Kaiser Creek in August 1986. Samples were delivered live to the University of California at Davis, Genetic Stock Identification Laboratory. Tissue extracts were prepared from each fish by standard methods, and stored frozen until analyzed. Standard horizontal starch-gel electrophoresis was used to identify allelic variability at seventeen biochemical marker-loci known to be diagnostic for variation among California rainbow trout populations (Busack et al. 1979).

Observed allele frequencies were compared to trout from present and former California steelhead streams ranging from the San Luis Rey River in the south, to the Eel River in the north, and to average allele frequencies for known coastal rainbow trout populations (Pit River hatchery stock, Lower Pit River and Lower McCloud River) using data on file in our laboratory. Fish from all these areas are referred to collectively as the "coastal rainbow" group (Berg and Gall 1988). In addition, allele frequencies for populations of redband type trout, *Oncorhynchus mykiss* sp., (upper Pit River, Goose Lake, and upper McCloud River) and golden trout, *O. aquabonita*, (Little Kern Basin, Kern River, and Volcano Creek) were used to determine if the trout from USL Reservoir could be distinguished from other *Oncorhynchus* species. Populations and abbreviations used for data presentation are identified by a number which represents relative electrophoretic migration in a starch-gel medium. Genetic similarities among populations were

**Table 1. Frequencies of alleles for Redwood Creek and Kaiser Creek, Upper San Leandro Reservoir, 1984 and 1986.**

| Locus | Allele | Frequencies | |
|---|---|---|---|
| | | Kaiser | Redwood |
| AAT-1 | 110 | | |
| | 100 | 0.990 | 1.000 |
| | 80 | 0.010 | |
| EST-3 | 100 | 0.970 | 1.000 |
| | 90 | 0.030 | |
| EST-4,5 | 100 | 0.461 | n.d.* |
| | 90 | 0.528 | n.d. |
| | 80 | 0.011 | n.d. |
| EST-6,7 | 110 | 0.026 | n.d. |
| | 100 | 0.464 | n.d. |
| | 90 | 0.510 | n.d. |
| GPI-3 | 100 | 0.990 | 0.803 |
| | 85 | 0.010 | 0.197 |
| IDH-3,4 | 180 | 0.010 | |
| | 170 | 0.264 | 0.155 |
| | 140 | 0.471 | 0.554 |
| | 100 | 0.005 | |
| | 60 | 0.250 | 0.291 |
| LDH-4 | 100 | 0.913 | n.d. |
| | 75 | 0.087 | n.d. |
| MDH-3,4 | 107 | | 0.053 |
| | 100 | 0.933 | 0.776 |
| | 85 | 0.067 | 0.020 |
| | 75 | | 0.151 |
| PGK-2 | 100 | 0.735 | 0.855 |
| | 80 | 0.265 | 0.145 |
| PGM-2 | 100 | 0.981 | 0.770 |
| | 85 | 0.019 | 0.230 |
| SOD-1 | 100 | 0.750 | 0.595 |
| | 60 | 0.250 | 0.405 |
| GL-2 | 120 | n.d. | |
| | 100 | n.d. | 0.806 |
| | 80 | n.d. | 0.194 |
| PGD | 120 | 0.263 | |
| | 100 | 1.000 | 0.737 |

*n.d. = not determined.

calculated using the methods of Nei (1978). Allele frequency comparisons were based on data for four enzyme systems of particular interest in the Redwood Creek and Kaiser Creek trout populations.

## RESULTS AND DISCUSSION

The general genetic profile for the USL Reservoir trout sampled from Kaiser and Redwood creeks (Table 1) was typical of that observed for coastal rainbow trout and different from that of redband and hatchery trout. Moreover, the USL

Reservoir trout contained unusual frequencies of variant alleles at four loci which characterized these trout as unique, isolated, and native stock (Table 2).

*Superoxide Dismutase (SOD-1)*: The most unusual frequency observed was for the slow 60 allele at the SOD-1 locus. While this allele is absent or occurs at very low frequencies in rainbow populations, it was observed at frequencies of 0.405 in Redwood Creek and 0.250 in Kaiser Creek. The 60 allele has been observed at low frequencies in rainbow trout populations from: the San Luis Rey River, an old isolated population; the Middle Fork Feather River; the North Fork Little Squaw Creek which drains into Lake Shasta; the lower Pit and McCloud rivers; and in steelhead from the Gualala River. This slow allele at SOD-1 is commonly found at high frequencies in golden trout from the Little Kern and Kern River drainages.

*Isocitrate dehydrogenase (IDH-3,4)*: Another genetic factor that links Kaiser Creek and Redwood Creek trout and separates them from other rainbow trout is the frequency of alleles at the IDH-3,4 locus pair. Not only do both populations have similar frequencies for two primary alleles (60 and 140), but they both possess unusually high frequencies of the 170 allele. The frequency was 0.155 in Redwood Creek and 0.264 in Kaiser Creek compared to only 0.013 and 0.016 in steelhead rainbow from the Gualala and Eel rivers, respectively. The 170 allele is also present at a high frequency in the Pit River (RTP) Hatchery stock and at low frequencies in trout from the lower and upper Pit River, North Fork Little Squaw Creek, Middle Fork Feather River, the lower and upper McCloud River, and the Sacramento River. However, it is absent in trout from the San Luis Rey River and Pauma Creek. The abundant 60 allele in the USL Reservoir stock is totally absent from RTP stock and several other loci [SOD-1, Glucose Phosphate Isomerase (GPI-3), and MDH-3,4] easily distinguish the Kaiser and Redwood Creeks stocks from RTP.

Conversely, the (100) allele is virtually absent in both Redwood and Kaiser Creek trout, which is in direct contrast to the high frequencies observed in the Feather River (0.208), North Fork Little Squaw Creek (0.365) and the upper Pit River and Goose Lake redband group (0.153). The RTP rainbow trout is the only other California stock found to possess a low frequency of the 170 allele and to also lack the 100 allele at the IDH-3,4 loci.

*Glucose Phosphate Isomerase (GPI-3)*: Trout from USL Reservoir are nearly unique in possessing the 85 allele at the most anodal GPI-3. This allele is not found in rainbow trout or steelhead from the Pit, McCloud, Sacramento, Gualala, or Eel rivers but occurs at a substantial frequency of 0.197 in Redwood Creek and at a frequency of 0.010 in Kaiser Creek. The only other location where this allele is known to occur among California trout is in the San Luis Rey River and its tributary, Pauma Creek, in southern California.

*Malate Dehydrogenase (MDH-3,4)*: Variation at the MDH-3,4 loci represents another example of the probable ancestral relationship of USL Reservoir trout to coastal (steelhead) rainbow trout. This is especially obvious for Redwood Creek trout which were segregating for all four alleles (75, 85, 100, and 107)

**Table 2. Redwood Creek and Kaiser Creek variation at key loci compared to similar stocks of rainbow and steelhead trout in California.**

| LOCUS | ALLELE | KC[a] | RC | SLR | PC | SR | GRS | ERS | FR | LSC | RTP | LPR | UPG | LMR | UMR | LKR | VC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SOD-1 | 170 | - | - | - | - | - | 0.008 | - | - | - | - | - | - | - | - | - | - |
| | 145 | - | - | 0.022 | 0.088 | 0.482 | 0.053 | 0.106 | - | 0.014 | 0.163 | 0.233 | 0.425 | 0.161 | 0.024 | - | 0.040 |
| | 100 | 0.750 | 0.595 | 0.848 | 0.912 | 0.518 | 0.886 | 0.894 | 0.958 | 0.972 | 0.837 | 0.714 | 0.575 | 0.825 | 0.976 | 0.353 | .0960 |
| | 60 | 0.250 | 0.405 | 0.130 | - | - | 0.053 | - | 0.042 | 0.014 | - | 0.053 | - | 0.014 | - | 0.647 | - |
| IDH-3,4 | 180 | 0.010 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 170 | 0.264 | 0.155 | - | - | 0.081 | 0.013 | 0.016 | 0.021 | 0.007 | 0.154 | 0.050 | 0.020 | 0.042 | 0.009 | - | - |
| | 140 | 0.471 | 0.554 | 0.897 | 0.941 | 0.759 | 0.659 | 0.692 | 0.604 | 0.446 | 0.846 | 0.821 | 0.757 | 0.740 | 0.543 | 0.152 | 0.950 |
| | 100 | 0.005 | - | - | - | 0.053 | 0.023 | 0.010 | 0.208 | 0.365 | - | 0.058 | 0.153 | 0.059 | 0.010 | 0.848 | 0.050 |
| | 60 | 0.250 | 0.291 | 0.103 | 0.059 | 0.107 | 0.305 | 0.282 | 0.167 | 0.182 | - | 0.071 | 0.070 | 0.159 | 0.438 | - | - |
| GPI-3 | 115 | - | - | 0.196 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 100 | 0.990 | 0.803 | 0.696 | 0.971 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| | 85 | 0.010 | 0.197 | 0.043 | 0.029 | - | - | - | - | - | - | - | - | - | - | - | - |
| | 60 | - | - | 0.065 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| MDH-3,4 | 107 | - | 0.053 | - | - | 0.054 | 0.005 | 0.022 | - | - | - | - | - | 0.001 | - | - | - |
| | 100 | 0.933 | 0.776 | 1.000 | 0.794 | 0.750 | 0.890 | 0.947 | 0.833 | 1.000 | 1.000 | 0.850 | 0.946 | 0.865 | 0.432 | 0.993 | 0.904 |
| | 95 | - | - | - | - | 0.009 | - | - | - | - | - | 0.021 | 0.006 | 0.036 | 0.547 | - | 0.094 |
| | 85 | 0.067 | 0.020 | - | 0.103 | 0.187 | 0.061 | 0.026 | 0.167 | - | - | 0.082 | 0.041 | 0.029 | 0.021 | - | 0.003 |
| | 75 | - | 0.151 | - | 0.103 | - | 0.044 | 0.005 | - | - | - | 0.047 | 0.007 | 0.069 | - | 0.007 | - |

[a]KC = Kaiser Creek - Upper San Leandro Reservoir; RC = Redwood Creek - Upper San Leandro Reservoir; SLR = San Luis Rey River- near San Diego; PC = Pauma Creek- near San Diego; SR = Sacramento River; GRS = Gualala River Steelhead; ERS = Eel River Steelhead; FR = Feather River; LSC = Little Squaw Creek; RTP = Pit River Hatchery; LPR = Lower Pit River; UPG = Upper Pit River and Goose Lake Redbands; LMR = Lower McCloud River; UMR = Upper McCloud River; LKR = Little Kern River Golden Trout; VC = Volcano Creek Golden Trout.

found in populations of Gualala and Eel river steelhead. The 107 and 75 allele appeared at higher frequencies that seen in any other group. These alleles are also found at lower frequencies in populations of coastal rainbows from the lower McCloud River. However, none of the six lower McCloud populations included in the composite frequencies (Table 2) possesses all four alleles. The absence of these two alleles from the Kaiser Creek sample could be due to sampling error or to genetic isolation among USL Reservoir populations; the frequency of the 100 allele for Kaiser Creek was exceptionally high for a steelhead population.

Because the rainbow trout in USL Reservoir have been isolated from ocean steelhead and because there were undoubtedly relatively few adult fish in the populations during the early years after Chabot Dam was constructed in 1875, the effects of genetic drift would be expected to have modified allele frequencies. Both founder effects and genetic drift are random and can result in increases or decreases in allele frequencies as well as the loss of alleles. These effects may have resulted in the trout in Redwood and Kaiser creeks taking on some very distinct characteristics with the Redwood Creek sample appearing to be the most unusual.

A genetic similarity analysis documented that Redwood and Kaiser Creek samples had a genetic identity of 0.993, indicating they probably represent a single population. Their genetic identity with coastal rainbows was 0.988, while their identity with inland, redband trout was 0.980, suggesting they are genetically more similar to coastal (steelhead) trout.

The genotype overlap method described by Ayala (1984) was used to determine the probability that trout from Redwood and Kaiser creeks could be assigned to any one of seven groups of California trout: coastal rainbow, inland redband, Pit River-Goose Lake redband, McCloud River redband, Kern River rainbow, Little Kern golden trout, and Volcano Creek golden trout (Table 3). The resulting analysis clearly demonstrated that the USL Reservoir trout are correctly assigned to the coastal rainbow group; the probability of assignment exceeded 70%.

**Table 3. Probability (%) of correct population group assignment based on Genotype Overlap Method (95% confidence = 68.9, 99% confidence = 74.1).**

| Population group | Probability | |
|---|---|---|
| | Kaiser | Redwood |
| Coastal Rainbow | 75.8 | 71.9 |
| Inland Redband | 13.0 | 17.9 |
| Goose Lake Redband | <0.1 | <0.1 |
| McCloud Redband | 2.1 | 2.6 |
| Kern River Rainbow | 2.1 | 0.4 |
| Little Kern Golden | 0.1 | 0.1 |
| Volcano Creek Golden | 6.8 | 7.3 |

In summary, all the genetic evidence strongly indicates that the Redwood and Kaiser Creek trout represent a unique group of coastal rainbow trout that have been isolated from migrating steelhead for over 100 years. Based on their overall genetic profile, their assignment to the coastal group, and their anadramous behavior, it is very appropriate to consider the Redwood Creek and Kaiser Creek trout to be direct descendants of native California steelhead that have not hybridized with domestic trout. The trout in the Upper San Leandro Reservoir should be considered scientifically valuable because of their unprecedented genetic integrity and they should be managed to conserve this uniqueness. Attention should also be given to other coastal reservoirs that may contain genetically uncontaminated, land-locked steelhead trout.

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# AGE AND GROWTH OF FLATHEAD CATFISH IN FOUR SOUTHWESTERN RIVERS[1]

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**Flathead catfish, *Pylodictis olivaris*, were introduced into major rivers of Arizona and California from about 1950-1975, and populations in the Gila, Salt, and Verde rivers, Arizona, and lower Colorado River, Arizona-California, now support important recreational fisheries. Age class structures and growth rates of these populations were estimated in 1986 by analysis of pectoral spines. Growth was similar in all rivers, although flathead catfish lived longest and attained largest size in the lower Colorado River. These southwestern populations had growth equal to or greater than flathead catfish in rivers within its native range in the eastern United States.**

## INTRODUCTION

The flathead catfish, *Pylodictis olivaris* (Rafinesque), is a large, piscivorous ictalurid native to lakes Michigan and Erie, and south in larger waters of the Mississippi, Missouri, and Ohio basins, Gulf of Mexico coastal plain, and Rio Grande drainage into Mexico (Moore 1968, Glodeck 1980, Becker 1983). This species supports important recreational and commercial fisheries throughout much of its range (Marsh et al. 1988).

Because of its large size and palatable flesh, flathead catfish have been introduced into parts of Arizona, California, Florida, Idaho, New Mexico, Oregon, and South Carolina (Gholson 1975, Moyle 1976). The first introduction in the southwest was to the Gila River system in New Mexico or Arizona sometime prior to 1950 (Miller and Lowe 1964). It was stocked in 1962 by Arizona Game and Fish Department (AZGFD) at six locations along the lower Colorado River (Bottroff et al. 1969), and subsequent introductions from 1968-1975 were in the Salt, Verde, and San Francisco rivers of Arizona (AZGFD files).

Flathead catfish have spread since initial introductions to inhabit waters throughout the lower Colorado, Gila, Salt, and Verde rivers in Arizona. Population size varied with discharge in the lowermost Colorado River, and was estimated to range from 155 to 259 flathead catfish per km when discharge was at a maximum in 1986 (Marsh et al. 1988). This species supports substantial fisheries and holds title to being the largest sport fish taken by angling in Arizona (29.5 kg, AZGFD files).

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The highly predatory nature of flathead catfish (Minckley and Deacon 1959, Hackney 1966, Minckley 1979, 1982; Layher and Boles 1980, Davis 1985) is detrimental to recovery efforts for native razorback sucker, *Xyrauchen texanus*, in the Gila River (Marsh and Brooks 1989).

Despite its successful colonization of all major Arizona drainages, its popularity with the angling public, and its impact on native fish communities and recovery efforts, flathead catfish life history in the southwest is not well known. As part of a comprehensive study to assess commercial potential of flathead catfish (Marsh et al. 1988), and to better understand its population dynamics in the southwestern United States, age and growth data were collected in 1986 from four major Arizona rivers.

## STUDY AREA AND METHODS

Flathead catfish were collected during May through July using a boat-mounted Coffelt RF-10, DC electroshocker along a 32.5 km reach of the lower Colorado River between Laguna and Morelos dams, Yuma County, Arizona and Imperial County, California (Fig. 1). Salt River, Gila County, Arizona, was sampled using a raft-mounted Smith Root VVP-15 electroshocker and/or 50 m-

FIGURE 1. The lower Colorado River Basin. Study areas on the lower Colorado, Gila, Salt, and Verde rivers are indicated by hatching.

long trammel nets (2.5 cm inner and 20.3 cm outer meshes) throughout the 59-km length upstream from Lake Roosevelt. Collections along the Verde River at accessible reaches downstream from Childs, Yavapai County to Bartlett Reservoir, Maricopa County, Arizona, were done using a boat- or raft-mounted electroshocker where practical, and 50 m trammel nets elsewhere. Gila River collections were made in the 77-km reach from the Arizona-New Mexico border, Greenlee County, downstream to Safford, Graham County, using a 115 volt AC, 850 W bank shocker.

Flathead catfish were measured to the nearest mm total length (TL) and weighed to the nearest 20 g in the field. Age and growth were determined by analyzing pectoral spine cross-sections (Marzolf 1955, Turner 1977). Left pectoral spines were disarticulated and excised, placed in scale envelopes to dry, and cut with a jeweler's saw. Thin sections were polished on very fine (no. 320) wet-dry sandpaper, and examined under alcohol and reflected light with a binocular microscope. Total spine diameter and lumen-to-each year mark radii were measured to the nearest 0.01 mm by ocular micrometer.

Back calculation of TL at time of each annulus formation was done using the equation $L' = C[S'/S(L-C)]$, where $L'$ is TL when the annulus was formed, L is TL at capture, $S'$ is spine radius to annulus, S is total spine radius, and C is the intercept value from the linear regression of L and S. Back-calculated lengths-at-age for the lower Colorado River sample were compared with length-frequency distributions from flathead catfish collected there in 1982-1986 (Marsh and Minckley 1987).

## RESULTS AND DISCUSSION

Flathead catfish spawning occurred in spring through early summer, as indicated by capture of small fish with no discernible annuli. Annulus formation in spring was apparently coincident with resumption of growth following cooler winter temperatures. We found no evidence among larger fish of false-annulus formation in response to potentially stressful mid-summer temperatures, which reached 28 degrees C in the lower Colorado River (Marsh and Minckley 1987).

The regression of TL versus S was based on 58 flathead catfish from the lower Colorado River, which yielded an equation of $TL = 17.41S + 15.20$ ($r = 0.989$). Separate calculations for other populations were precluded because sample sizes were small for the Gila, Salt, and Verde rivers (the species was difficult to obtain in those areas), and distributions of total lengths for those rivers were biased toward larger individuals. Carlander (1982) expressed the importance of using a constant intercept among populations of the same species, which enables more accurate comparisons by reducing unnatural variability among growth computations. We derived back-calculated lengths using 15 mm as the constant for TL at time of spine formation in all populations.

Enlargement of the pectoral spine lumen (Muncy 1957, Turner 1977) occurred among flathead catfish from all rivers, but was especially troublesome in the

**Table 1. Pectoral spine mean year mark radii for growth years 1, 2, and 3 for 67 flathead catfish from the lower Colorado River, Arizona-California.**

| | Year 1 | Year 2 | Year 3 |
|---|---|---|---|
| *n* | 15 | 27 | 25 |
| Mean annular radius (mm) | 0.30 | 1.03 | 2.14 |
| SD | 0.09 | 0.23 | 0.64 |
| Range | 0.23-0.45 | 0.53-1.50 | 1.30-3.00 |

lower Colorado River population. This enlargement is due to natural processes of bone formation, which tend to de-emphasize deposition of calcium phosphate in central (relative to external) portions of the structure, and becomes more pronounced in older individuals. As a result of this phenomenon, more than 90% of Colorado River fish 3 years and older were missing the first year annulus, and depending on year class, 23 to 75% of the fish that were 4 years and older were also missing the second year annulus. Failure to account for missing annuli results in biases toward younger ages and faster growth. To correct these biases, annuli from spine sections with little or no lumen enlargement were measured to estimate a mean and standard deviation (SD) for annuli 1, 2, and 3 (Table 1). Lumen radii were then measured, and if found to be greater than annular means plus 1 SD, the age would be increased the corresponding number of years. The mean plus 1 SD, rather than the mean, was used to account for natural variation among lumen diameters.

Back-calculated lengths agreed well with modes in length-frequency distributions of 884 flathead catfish collected from the lower Colorado River in 1982-86 (Marsh and Minckley 1987), and we considered the spine method of aging valid for this and the other rivers. The method was previously validated from returns of tagged flathead catfish in the Des Moines River, Iowa (Muncy 1957), and in Lake Carl Blackwell, Oklahoma (Turner 1977).

Flathead catfish from the lower Colorado River ($n$ = 98) ranged from 0 to 9 years of age, and included representatives of 1977 to 1986 year classes (Table 2). Young-of-the-year averaged 71 mm at capture; the largest individual was 1,010 mm TL and 9 years old. Back-calculated lengths at each age varied somewhat among year classes, but weighted means for each year class had relatively small SD's (Table 2). Average annual growth varied considerably among years, and was greatest during the third year.

Samples from the Gila River ($n$ = 24) included 1981 to 1986 year classes, with individuals that ranged from 1 to 5 years old (Table 3). Young-of-the-year averaged 103 mm at capture; the largest specimen was 520 mm TL and 5 years old. Annual growth was relatively consistent for a given age among year classes, and average annual growth was greatest during the first year of life.

The Salt River produced flathead catfish ($n$ = 34) that ranged in age from 1 to 6 years, and represented 1980 through 1985 year classes (Table 4). No young-of-the-year were collected; the largest fish was 707 mm TL and 6 years old.

**Table 2. Back-calculated total length (TL) at each annulus of flathead catfish from the lower Colorado River.**

| Year class | Age group | Number of Fish | TL at capture | | Year of Life | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | Range | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1986 | 0 | 7 | 71±8[a] | 58-77 | | | | | | | | | |
| 1985 | I | 14 | 158±45 | 86-210 | 63±15 | | | | | | | | |
| 1984 | II | 5 | 309±41 | 263-358 | 84±26 | 171±37 | | | | | | | |
| 1983 | III | 16 | 523±65 | 407-612 | 104±35 | 205±51 | 453±87 | | | | | | |
| 1982 | IV | 43 | 573±56 | 468-670 | 124±28 | 192±53 | 370±90 | 520±58 | | | | | |
| 1981 | V | 6 | 643±58 | 578-648 | - | 208±88 | 337±66 | 498±70 | 598±42 | | | | |
| 1980 | VI | 4 | 695±28 | 676-736 | - | 194±44 | 317±50 | 414±90 | 591±56 | 649±40 | | | |
| 1979 | VII | 2 | 798±38 | 772-825 | - | - | 332±21 | 426±75 | 511±81 | 722±33 | 767±40 | | |
| 1978 | VIII | 0 | - | - | - | - | - | - | - | - | - | | |
| 1977 | IX | 1 | 1,010 | | - | - | - | 415 | 644 | 758 | 827 | 930 | 976 |
| Weighted mean TL | | | 474 | | 106±23 | 195±9 | 382±42 | 455±51 | 586±55 | 710±56 | 798±42 | 930 | 976 |
| Mean annual growth | | | | | 106 | 89 | 187 | 73 | 131 | 124 | 88 | 132 | 46 |

[a]Mean ± 1 SD.

**Table 3. Back-calculated total length (TL) at each annulus of flathead catfish from the upper Gila River.**

| Year class | Age group | No. of fish | TL at capture | | Year of Life | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | Range | 1 | 2 | 3 | 4 | 5 |
| 1986 | 0 | 8 | 103±25[a] | 62-138 | | | | | |
| 1985 | I | 5 | 195±53 | 112-265 | 148±51 | | | | |
| 1984 | II | 1 | 281 | - | - | 226 | | | |
| 1983 | III | 1 | 345 | - | 136 | 180 | 327 | | |
| 1982 | IV | 8 | 429±29 | 400-478 | 121±26 | 253±52 | 318±39 | 400±28 | |
| 1981 | V | 1 | 520 | - | 114 | 296 | 404 | 454 | 503 |
| Weighted mean TL | | | 266 | | 130±14 | 248±28 | 327±27 | 406±18 | 503 |
| Average annual growth | | | | | 130 | 118 | 79 | 79 | 97 |

[a]Mean ± 1 SD.

**Table 4. Back-calculated total length (TL) at each annulus of flathead catfish from the Salt River.**

| Year class | Age group | No. of fish | TL at capture | | Year of Life | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | Range | 1 | 2 | 3 | 4 | 5 | 6 |
| 1986 | 0 | - | | | | | | | | |
| 1985 | I | 12 | 200±57[a] | 134-298 | 123±48 | | | | | |
| 1984 | II | 10 | 371±56 | 257-447 | 137±58 | 274±57 | | | | |
| 1983 | III | 3 | 486±35 | 448-516 | 141±22 | 285±70 | 401±34 | | | |
| 1982 | IV | 2 | 600 | - | - | 218±26 | 477±35 | 562±16 | | |
| 1981 | V | 6 | 628±56 | 563-706 | - | 213±35 | 344±25 | 473±39 | 593±50 | |
| 1980 | VI | 1 | 707 | - | - | 271 | 331 | 459 | 510 | 613 |
| Weighted mean TL | | | 390 | | 131±8 | 254±31 | 379±53 | 491±40 | 581±31 | 613 |
| Average annual growth | | | | 131 | 123 | 125 | 112 | 90 | 32 | |

[a]Mean ± 1 SD.

Annual growth varied among year classes, but was overall relatively constant. Mean annual growth was greatest during the first year, slightly less during the second and third years, and reduced thereafter.

Flathead catfish from the Verde River ($n$ = 46) ranged in age from 0 to 8 years and included 1978 to 1986 age classes (Table 5). Total length at capture was 145 mm for the one young-of-the-year fish sampled and 920 mm for the largest, an 8 year-old fish. Mean annual growth among year classes varied substantially for certain years, although this was generally not reflected in deviations of weighted mean lengths which remained small. Average annual growth was greatest during the third year of life.

**Table 5. Back-calculated total length (TL) at each annulus of flathead catfish from the Verde River.**

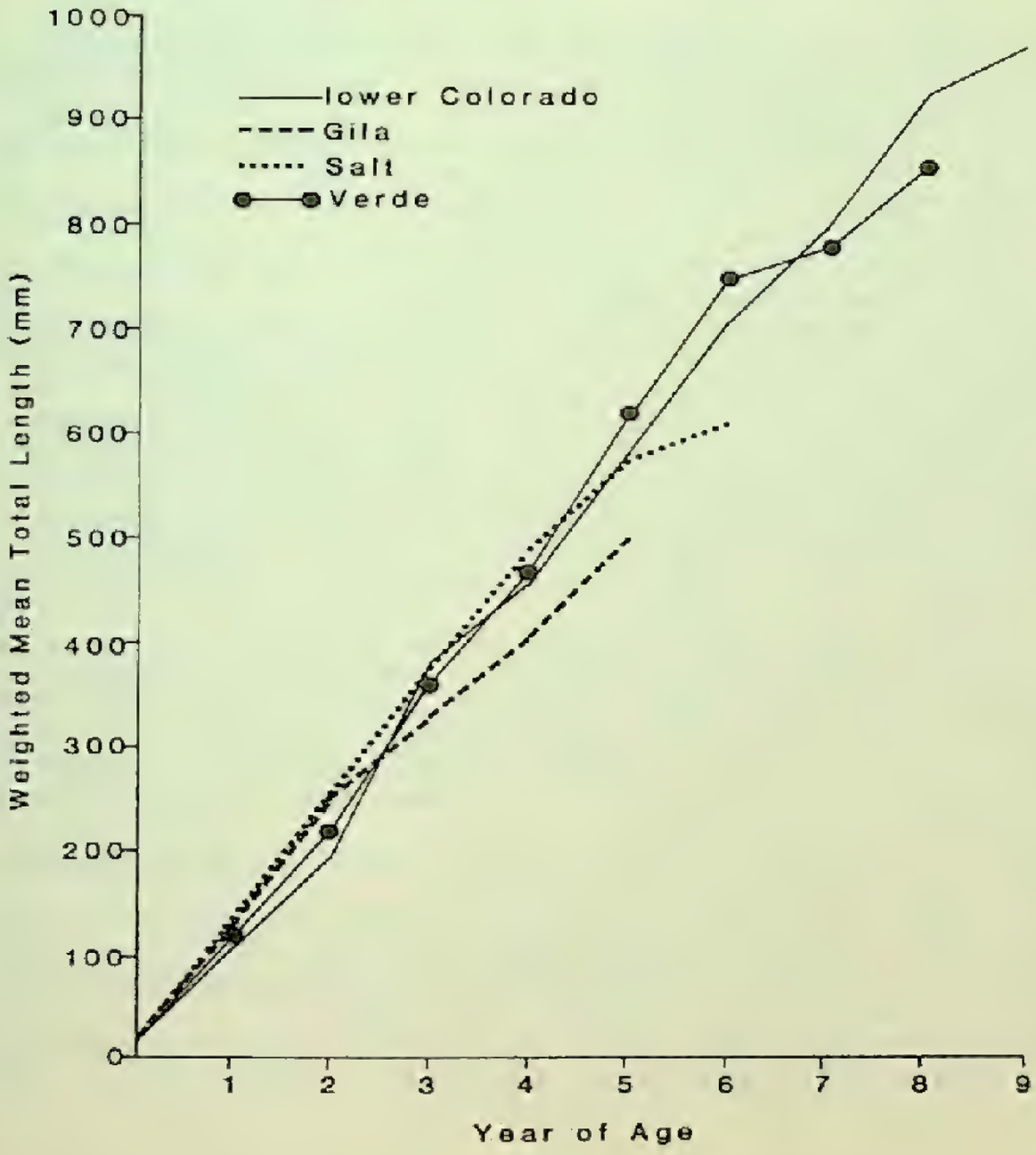
| Year class | Age group | Number of Fish | TL at capture | | Year of Life | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | Range | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1986 | 0 | 1 | 145 | - | | | | | | | | |
| 1985 | I | 4 | 164±14[a] | 152-182 | 97±33 | | | | | | | |
| 1984 | II | 12 | 263±62 | 192-396 | 101±43 | 195±55 | | | | | | |
| 1983 | III | 15 | 424±61 | 304-506 | 111±26 | 240±56 | 366±48 | | | | | |
| 1982 | IV | 6 | 501±52 | 434-570 | 125±18 | 221±57 | 375±75 | 454±46 | | | | |
| 1981 | V | 5 | 635±45 | 560-681 | 188±15 | 244±71 | 335±86 | 453±89 | 596±31 | | | |
| 1980 | VI | 0 | - | - | - | - | - | - | - | - | | |
| 1979 | VII | 0 | - | - | - | - | - | - | - | - | - | |
| 1978 | VIII | 2 | 920±28 | 900-940 | - | - | 348±26 | 560±90 | 685±75 | 747±54 | 785±54 | 862±28 |
| Weighted mean TL | | | 408 | | 118±27 | 223±21 | 362±14 | 470±40 | 621±43 | 747±56 | 785±54 | 862±28 |
| Mean annual growth | | | | | 118 | 105 | 139 | 108 | 151 | 126 | 38 | 72 |

[a]Mean ± 1 SD.

Although no statistical differences in annual growth rates among rivers were detected (t-test, $P > 0.10$), flathead catfish from the Gila and Salt rivers appeared to grow faster during the first two years of life than those in the Verde and lower Colorado rivers (Fig. 2). Gila River fish exhibited the slowest growth beyond the third year. Lower Colorado River fish lived longer and attained larger sizes than fish in the other Arizona rivers.

Among riverine populations, flathead catfish growth rates in Arizona rivers were generally greater than in Salt River, Missouri (Purkett 1958), Missouri River, Nebraska (Morris et al. 1971); similar to rates in the Big Blue and Neosho rivers, Kansas (Minckley and Deacon 1959); and slower than in the Coachella Canal, California (Pisano et al. 1983). Although Sneed et al. (1961) suggested that flathead catfish growth was faster in reservoirs than in rivers, recent data

FIGURE 2. Growth in total length of flathead catfish in the Gila, Salt and Verde rivers, Arizona, and the lower Colorado River, Arizona-California.



indicate that reservoir populations have more variable growth rates, and generally have similar ranges to those of river-dwelling stocks (Guier et al. 1979). Growth of flathead catfish in the lower Colorado River is as rapid, at least through 9 years, as anywhere reported in the species' range.

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# FISH REMAINS FROM NINE ARCHAEOLOGICAL SITES IN RICHMOND AND SAN PABLO, CONTRA COSTA COUNTY, CALIFORNIA[1]

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**At least 34 species of fishes are represented among the remains recovered during excavations of nine archaeological sites in Richmond and San Pablo of western Contra Costa County, California. Of the 6,993 elements identified, most are from the sturgeon (2,549), sardine or herring (1,510), salmon (1,135) and bat ray (944). Marine, euryhaline and freshwater species are represented and probably reflect the exclusively local exploitation of fishery resources by the Costanoan Native American fishermen. Based on these remains, splittail, hitch and hardhead are recorded for the first time from San Pablo Creek. Ten of the species found here have not been previously reported from middens on the San Francisco Bay. These remains are from sites that date back to more than 3,000 years before present.**

## INTRODUCTION

The remains of fishes that are associated with archaeological sites of native Americans not only provide information concerning dietary habits and fishing methods of prehistoric peoples, but contribute to our understanding of zoogeography (Gehlbach and Miller 1961, Gobalet 1990). They may also provide information regarding the population dynamics of species in ecosystems that have been dramatically altered during historic times (e.g., Schulz and Simons 1973, Schulz 1979). In the Richmond-San Pablo region of the San Francisco Bay area, the containment of streams forced by rapid urbanization has resulted in an alteration of the waterways to an extent that it is potentially catastrophic to the aquatic life of the area (Nichols et al. 1986); indeed many local environments no longer contain the pristine fish fauna reported by Skinner (1962) or Leidy (1984). This is a local manifestation of a far greater problem addressed by Miller (1961).

Far too often the findings from archaeological investigations receive limited distribution since they are published in site reports that satisfy legal requirements for environmental analysis of development projects and become part of the gray literature. It is the objective of this paper to reach a broader audience and to report on the fish remains found at nine archaeological sites in the Richmond-San Pablo region of western Contra Costa County, California.

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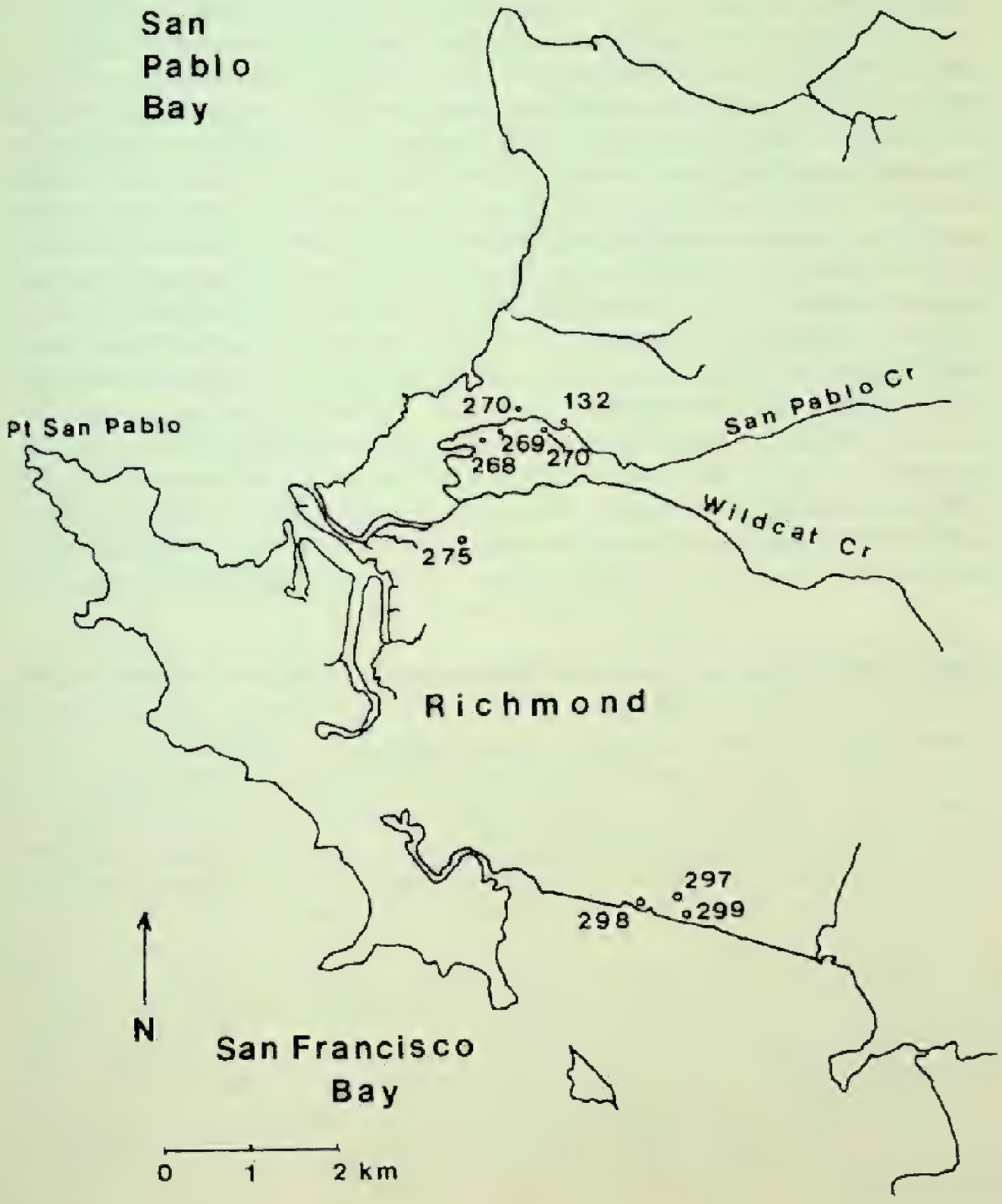
Nine sites were sampled. The six northern sites (CA-CCO-132, -268 through -271, and -275) are located along the lower reaches of Wildcat or San Pablo Creeks which arise in the San Pablo Hills to the east and flow into San Pablo Bay, a portion of the San Francisco Bay (Fig. 1). The three southern sites (CA-CCO-297, -298, and -299), collectively known as the Stege Mounds, are located along

FIGURE 1. Location of the study sites in the San Francisco Bay area of California.



the northeastern perimeter of the San Francisco Bay within the Richmond Harbor area. Testing and mitigation studies were undertaken in the area on archaeological sites CCA-CCO-268 through -271 (Banks and Orlins 1979), CA-CCO-269 and 270 (J. Holson, unpubl. data), CA-CCO-275 (Banks and Orlins 1980), CA-CCO-297 (Banks and Orlins 1987), CA-CCO-297 and 298 (Banks and Orlins 1981), CA-CCO-299 (Banks and Orlins 1985). These site reports have not been widely circulated, but are on file at the Northwestern Information Center, California Archaeological Inventory, Sonoma State University, Rohnert Park. Contributions on the fish remains appear in these reports.

The primary period of occupation was the Middle Horizon Period (1,000 B.C. to A.D. 500) though some occupation is indicated during the Early and Late Horizon (Table 1). The occupants were Costanoan (Ohlone) speaking and prior to European contact in the 1770's, they ranged from San Pablo Bay south to Monterey along the coastal ranges of California (Moratto 1984). The Huchiun tribelet was the largest group of Costanoan speakers in the San Francisco Bay area with a population of 580-800 people occupying the region from Rodeo Creek in Contra Costa County to Temescal Creek in Emeryville, Alameda County (Milliken 1981). The Richmond-San Pablo area contained a pair of villages totaling 100-200 persons in 1772 according to the early records of Pedro Fages and Father Crespi (see Milliken 1979). High population densities were probably maintained by the rich resources of the diverse estuarian habitat. However, these actual numbers sound low and perhaps disease had already lowered numbers by the 1770's. The exploitation of fishes was quite extensive. Loud (1924) found 527 stone net sinkers at one Stege Mound, CA-CCO-300, and Follett (1975*b*) suggested the use of watercraft, seines and gill nets at the West Berkeley shellmound (CA-Ala-307) about 5.6 km south of the Stege Mounds.

**Table 1. Period of occupation of sites within Richmond-San Pablo area[a] (modified from Banks and Orlins 1981).**

| | Date of transition | | | | |
|---|---|---|---|---|---|
| | | | | Phase 1 | Phase 2 |
| | 1,000 B.C. | | A.D. 500 | 1500 | 1770 |
| Site | Early horizon | Middle horizon | | Late horizon | Late horizon |
| CCO-268 | | X | | | |
| CCO-269 | | X | | | |
| CCO-270 | | X | | | |
| CCO-271 | | X | | X | |
| CCO-275 | X | X | | X | |
| CCO-297 | | | | X | X |
| CCO-298[b] | X | X | | | X |
| CCO-299 | | | | X | |
| CCO-300 | X | X | | | |

[a]Based on radiocarbon dates, artifacts, and/or obsidian hydration.
[b]Banks and Orlins (1985).

## METHODS

Most of the fish remains were obtained by using 1/4 in. and 1/8 in. mesh screens, a technique biased toward the recovery of remains of large fish (Fitch 1969, Casteel 1972). Column samples from sites CA-CCO-269, -297, -298 and -299 were subject to microscopic analysis. The column sample from CA-CCO-269 was screened with 40 mesh/in using the methods of Fitch (1969). These materials have been deposited at the Archaeology Laboratory of Contra Costa College, San Pablo, California.

Identifications were made by comparison with museum fish skeletons and scales from the California Academy of Sciences; the Museum of Anthropology, University of California at Davis; California State University, Bakersfield; and University of California, Los Angeles. Radiographs were taken of elasmobranch centra at the Veterinary Hospital of the University of California, Davis and compared with those of L.J.V. Compagno, then of Stanford University. Compagno identified the seven gill shark tooth and angel shark centra.

Identifications are made to the lowest possible taxon following the nomenclature of Robins et al. (1980). Distinguishing between the green sturgeon, *Acipenser medirostris* and white sturgeon, *A. transmontanus*, based on limited skeletal materials was not attempted for reasons elaborated by Follett (1975*b*). Because diagnostic bones were not present, the atherinids may be either topsmelt, *Atherinops affinis*, or jacksmelt, *Atherinopsis californiensis*; the clupeids either the Pacific herring, *Clupea harengus*, or Pacific sardine, *Sardinops sagax*; the salmon are probably chinook, *Oncorhynchus tshawytscha*, or coho, *O. kisutch*; the rockfish, any of dozens of species in the genus *Sebastes*.

## RESULTS AND DISCUSSION

A minimum of thirty-four species of fishes were identified in these studies (Table 2, Table 3). Gobalet (unpubl. data) reported 36 species alone, in another record of remains at CA-CCO-297. Included however, were four exotic species and considerable other evidence of recent perturbation of the site; these remains are evidently historic and were not considered in this study. Loud (1924) indicated that the site had been leveled prior to 1924. Follett (1975*a*) previously reported the remains of sturgeon, leopard shark, *Triakis semifasciata*, and white sea bass, *Atractoscion nobilis*, from the Stege Mounds (probably CCO-298 or CCO-300) in Richmond, California.

The exploitation of a diversity of aquatic habitats by Native Americans is indicated because the fish species are either marine, freshwater, or those that move between these habitats (Table 2). Natural history summaries of these species can be found in Skinner (1962), Moyle (1976), or Eschmeyer, Herald and Hamman (1983). Excellent reviews of the fishing techniques used by the native fishermen are found in Rostlund (1952), Follett (1974, 1975*b*) and Salls (1988).

**Table 2. Fishes identified from archaeological sites in Contra Costa County, California.**

| Marine taxa | Common name |
|---|---|
| *Myliobatis california* | bat ray |
| Rajiidae[a] | skates |
| *Squatina california* | Pacific angel shark |
| *Triakis semifasciata* | leopard shark |
| *Galeorhinus zyopterus*[a] | soupfin shark |
| *Squalus acanthias* | spiny dogfish |
| *Notorynchus maculatus* | sevengill shark |
| Clupeidae | Pacific herring, Pacific sardine |
| *Engraulis mordax* | northern anchovy |
| *Porichthys notatus* | plainfin midshipman |
| Atherinidae | topsmelt, jacksmelt |
| *Atractoscion nobilis* | white seabass |
| *Amphistichus* sp. | barred, calico, redtail surfperch |
| *Cymatogaster aggregata* | shiner perch |
| *Embiotoca* sp. | black perch or striped seaperch |
| *Hyperprosopon* sp. | spotfin, walleye, silver seaperch |
| *Hypsurus caryi* | rainbow seaperch |
| *Phanerodon furcatus*[a] | white seaperch |
| *Rhacochilus toxotes* | rubberlip seaperch |
| *R. vacca* | pile perch |
| *Cebidichthys violaceus* | monkeyface prickleback |
| *Sebastes* sp. | rockfish |
| *Citharichthys sordidus*[a] | Pacific sanddab |
| Euryhaline taxa | |
| *Acipenser* sp. | white or green sturgeon |
| *Dorosoma petenense*[b] | threadfin shad |
| *Oncorhynchus* sp. | chinook or coho salmon |
| *Morone saxatilis*[b] | striped bass |
| Embiotocidae | surfperches |
| Gobiidae | gobies |
| *Gillichthys mirabilis* | longjaw mudsucker |
| Cottidae | sculpins |
| *Platichthys stellatus* | starry flounder |
| Freshwater taxa | |
| Cyprinidae | minnows |
| *Pogonichthys macrolepidotus* | splittail |
| *Lavinia exilicauda*[a] | hitch |
| *Mylopharodon conocephalus*[a] | hardhead |
| *Catostomus occidentalis* | Sacramento sucker |

[a]Doubtful identification.
[b]Introduced species.

The bat ray, *Myliobatis californica*, (944), sturgeon (2,549), Pacific sardine or Pacific herring (1,510), and salmon (1,135) are the most abundant (Table 3) in numbers of elements identified. Since sampling techniques varied at each site and because microscopic examinations were undertaken only at sites CCO-269, CCO-297 and CCO-298, comparisons between sites on the availability or the preference for these fishes by the aboriginals are speculative.

The bat ray, attaining a weight of 95 kg (Miller and Lea 1972), white sturgeon, 629 kg in California (Fry 1973 in Follett 1975*a*), and chinook salmon, 57.5 kg

**Table 3. Number of elements identified by archaeological site.**

| Species | CCO -132 | CCO -268 | CCO -269 | CCO -270 | CCO -271 | CCO -275 | CCO -297 | CCO -298 | CCO -299 |
|---|---|---|---|---|---|---|---|---|---|
| Leopard shark | | 2 | 2 | 1 | | 4 | 155 | 13 | 2 |
| Bat ray | 2 | 40 | 492 | 13 | 4 | 27 | 310 | 21 | 35 |
| Sturgeon | 36 | 40 | 1,908 | 190 | 71 | 112 | 160 | 27 | 5 |
| Sardine or herring | | | 2 | | | | 1,338 | 170 | |
| Northern anchovy | | | | | | | 19 | 5 | |
| Salmon | 15 | 59 | 658 | 201 | 54 | 26 | 40 | 77 | 5 |
| Minnows or suckers | | 1 | 4 | | 2 | | | | |
| Splittail | | | 6 | 1 | 3 | | | | |
| Sacramento sucker | | 6 | 2 | | | | | | |
| Plainfin midshipman | | 4 | 58 | 11 | 1 | 16 | 35 | 2 | 2 |
| Topsmelt or jacksmelt | | | 62 | 5 | 2 | | 117 | 11 | 5 |
| White seabass | | | | | | | 22 | | |
| Barred, calico, or redtail surfperch | | 1 | 1 | | | | 74 | | |
| Black perch or striped seaperch | | 10 | | 3 | 2 | | 53 | 2 | |
| Rainbow sea perch | | | 1 | | | | 7 | | |
| Spotfin, walleye, or silver surfperch | | 2 | | 2 | | | 1 | | |
| Rubberlip seaperch | | | | | | | 7 | | |
| Pile perch | | | | | | | 9 | 1 | |
| Surfperches | | 3 | 9 | 7 | | 1 | 16 | 2 | |
| Longjaw mudsucker | | | 2 | 6 | | | 6 | | |
| Starry flounder | | | | | 1 | | 4 | | |
| Rockfish | | | | | | | 24 | | |
| Total[a] | 53 | 163 | 3,213 | 466 | 140 | 187 | 2,405 | 332 | 54 |

[a]Total includes miscellaneous: Soupfin skark (CCO-270, 2 elem.); angel shark (CCO-297, 1 elem.); skate (CCO-297, 2 elem.); spiny dogfish (CCO-298, 1 elem.); sevengill shark (CCO-275, 1 elem.); threadfin shad (CCO-298, 3 elem.); hitch (CCO-271, 1 elem.); hardhead (CCO-271, 1 elem.); striped bass (CCO-269, CCO-297, 1 elem. ea.); monkeyface prickleback (CCO-270, 2 elem.); white seaperch (CCO-268, 1 elem.); shiner perch (CCO-297, 1 elem.) goby (CCO-297, 1 elem.); sculpin (CCO-297, 2 elem.); Pacific sanddab (CCO-269, 1 elem.).

(Miller and Lea 1972), are all large species that would have been significant and reliable food sources. The Pacific herring and Pacific sardine are of lesser size but nevertheless reach 45 cm in total length (Miller and Lea 1972). The superabundance of sturgeon at CCO-269 suggests ready availability of the anadromous sturgeons from San Pablo Bay, its sloughs and possibly San Pablo Creek. A single modest-sized sturgeon (10-25 kg) would contain considerably more meat than hundreds of silversides or herring or dozens of minnows. Thus the numbers of elements identified do not reflect the edible portion available from each fish.

The anadromous coho salmon and the freshwater Sacramento sucker, *Catostomus occidentalis*, have been recorded from San Pablo Creek by Leidy (1984). Remains questionably identified as splittail, *Pogonichthys macrolepidotus*, from CA-CCO-269, -270, and -271, hitch, *Lavinia exilicauda*, and hardhead, *Mylopharodon conocephalus*, from CCO-271, if taken from the adjacent San Pablo Creek, as seems reasonable, document the prehistoric presence of these freshwater minnows. The paucity of remains from the suckers and minnows, however, would argue against their being a significant resource or a reliable indicator of zoogeography. If the salmon taken were coho, San Pablo Creek itself would be the likely source. However, if the salmon were chinook salmon, it is reasonable to assume that watercraft were used in San Pablo Bay to capture these fish during their migrations into the Sacramento and San Joaquin Rivers (see Skinner 1962). Evidence here suggests that both the creek and bay were extensively exploited.

Data from CCO-268 through -271, and -275 all indicate similar exploitation of the fishes characteristic of the region with obvious differences from the fishes exploited at sites CCO-297 through -299, located just 9 km southeast at the present Richmond Harbor (Fig. 1). Fishes found at the southern sites, but not at the northern ones, are the surfperches (*Amphistichus* sp., *Cymatogaster aggregata*, *Embiotoca* sp., and *Rhacochilus* sp.), Pacific herring and Pacific sardine, white sea bass, rockfishes and northern anchovy, *Engraulis mordax*. These fishes are all generally found in rocky areas or more open water, the environments of Richmond Harbor. The exclusively freshwater fishes are found only at the sites on San Pablo Creek and Wildcat Creek to the north. Sturgeon, salmon, and bat ray are commonly found at archaeological sites throughout the San Francisco Bay area and at both the northern and southern sites studied here. These data suggest local exploitation and no trade for fishes from distant locations.

Fishes reported from these nine archaeological sites that have not been previously found at other sites in the immediate San Francisco Bay area are the Pacific angel shark, *Squatina californica*, spiny dogfish, *Squalus acanthias*, sevengill shark, *Notorynchus maculatus*, northern anchovy, shiner perch, *Cymatogaster aggregata*, Pacific sanddab, *Citharichthys sordidus*, longjaw mudsucker, *Gillichthys mirabilis*, splittail, hitch and hardhead. It is possible that remains of these fishes have been identified at sites in the Bay Area, but the findings are in poorly distributed site reports. The remains of the two introduced

species identified here, the threadfin shad, *Dorosoma petenense*, and striped bass, *Morone saxatilis*, were found near the surface of the sites where recent deposition would be expected.

Since the marine fishes of the three southern sites tend to be open water forms or those that inhabit rocky areas, the local aquatic habitat has apparently changed little from the time of aboriginal occupation. The diversity of species at the six northern sites however, indicates a variety of aquatic habitats. The Costanoans used watercraft to fish the open bay (Follett 1975*b*) but probably exploited the extensive salt marshes that fringed the San Pablo Bay as well. Sturgeon and bat ray could have been speared or netted in shallow marshy waters. The exclusively freshwater species are noteworthy. Since splittail and hitch are found in slow moving waters, hardhead in undisturbed sections of streams, and Sacramento suckers in a variety of habitats (Moyle 1976), it appears that San Pablo Creek flowed year-round to maintain populations of freshwater fishes. It would have terminated in a marshy freshwater delta that graded into the salt marsh. Sturgeon and salmon probably ascended its main channel. This suggested habitat is in marked contrast to that of today where, if the streams flow at all, it is through reclaimed marshland down canals maintained for flood control. The sluggish freshwater habitat of the native species is clearly no longer present. Conservation efforts might be directed toward reestablishing the freshwater marsh.

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# NATIVE STATUS OF SACRAMENTO PERCH (*ARCHOPLITES INTERRUPTUS*) IN ALAMEDA CREEK, ALAMEDA COUNTY, CALIFORNIA: EVIDENCE FROM ARCHAEOLOGICAL SITE CA-ALA-483

Documenting the native ranges of freshwater fishes becomes increasingly difficult (sometimes impossible) as aquatic habitats are altered for flood control, agriculture and urban development. Leidy (1984) summarized the surveys of fishes made in the Alameda Creek drainage of the eastern San Francisco Bay, California, between 1905 and 1981. No Sacramento perch, *Archoplites interruptus*, were collected in the drainage prior to 1953. Their occurrence has been considered the result of introductions to Calaveras Reservoir sometime after its construction in 1924 (Aceituno et al. 1976). This assessment is surprising because Sacramento perch are native to the Sacramento-San Joaquin system freshwater fish complex (Hopkirk 1973, Moyle 1976). Because Alameda Creek is within the system, Sacramento perch were undoubtedly present. Though today saltwater in the San Francisco Bay acts as a barrier to dispersal of freshwater fishes from one freshwater tributary of the Bay to another, Evermann and Clark (1931) noted records (1854-1862) of fishes of the Sacramento-San Joaquin complex, including Sacramento perch, in San Francisco Bay following unusually heavy floods. Sacramento perch also have unusually high tolerance to salinity which would promote their survival and ability to disperse. Consequently one would expect records to show Sacramento perch in Alameda Creek prior to 1953.

In the Salinas River where the native status of the Sacramento perch was questioned by Hubbs (1947), the findings of this native sunfish among the remains at archaeological sites CA-MNT-233 (Mission La Soledad Cemetery) (Follett 1972; Salls 1989) and CA-MNT-229 (Elkhorn Slough) (Gobalet 1990) have helped document its status as a native.

Fish remains recovered during the excavation of archaeological site CA-ALA-483 located along Arroyo de la Laguna, a tributary of Alameda Creek (Fig. 1) have provided evidence for establishing the Sacramento perch as a native in the drainage. CA-ALA-483 is in the town of Pleasanton, west of the intersection of Interstate 680 and Bernal Avenue. This site was excavated in late 1989 by Basin Research Associates, Inc. of San Leandro, California. Soil was removed by hand and backhoe and washed through 1/8 in. mesh screens with a fire hose. Only vertebrae were recovered (Table 1). Identifications were made by comparison with specimens at California State University, Bakersfield.

This fauna is quite similar to that of the Stone Lake archaeological site (CA-SAC-145) in the Sacramento River Delta where Schulz and Simons (1973) found 51% Sacramento perch, 39% minnows (Cyprinidae: thicktail chub, Sacramento blackfish, hitch, splittail), 6% sucker, *Catostomus occidentalis*, and 1% tule

FIGURE 1. Location of archaelogical site CA-ALA-483 in the drainage of Alameda Creek, Alameda Co., California.

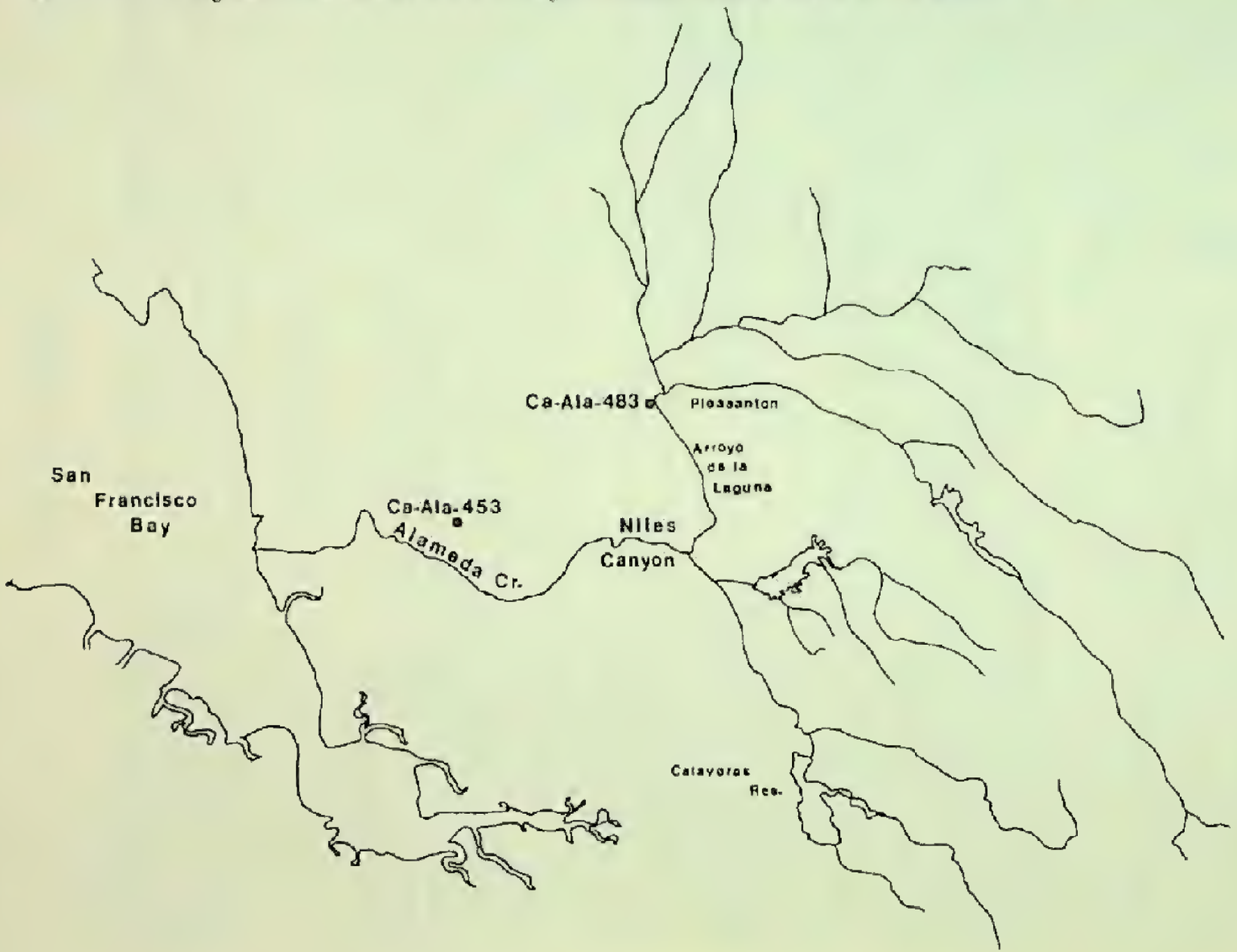

**Table 1. Summary of Fish Remains Recovered During Excavation of CA-Ala-483.**

| Common name | Scientific name | Number of vertebrae |
|---|---|---|
| Sacramento perch | *Archoplites interruptus* | 230 |
| Minnows | Cyprinidae | 133 |
| Sacramento sucker | *Catostomus occidentalis* | 24 |
| Tule perch | *Hysterocarpus traskii* | 6 |
| Undetermined bony fish | | 33 |
| Total | | 426 |

perch, *Hysterocarpus traskii*. Differential preservation certainly influences these percentages. The habitat favored by this fish assemblage was slow moving rivers, marshes, sloughs and lowland lakes (Moyle 1976). Willow Marsh adjacent to CA-ALA-483 had such an environment at least until 1878 (Thompson and West map 1878). The entire marsh has since been reclaimed and developed, a trend that has left less than 4% of the original riparian wetland statewide (Nature Conservancy 1987). Radiocarbon dates and artifacts indicate the extended occupation of the site beginning at least 1465 B.C. and confirm the prehistoric presence of Sacramento perch in the drainage. Additional corroborative evidence was provided by P. D. Schulz (Calif. Dept. Parks and Recreation, pers. comm.) who found two Sacramento perch bones from another archaeological site in the Alameda Creek drainage (CA-ALA-483 in Union City) (Fig. 1). The deposits from which they have been recovered are dated between A.D. 1 and A.D. 600.

Characters distinguishing the vertebrae of minnows are subtle and often tentative. Remains of all four lowland cyprinids may be present among the 133 vertebrae: splittail (*Pogonichthys macrolepidotus*), thicktail chub (*Gila crassicauda*), Sacramento blackfish (*Orthodon microlepidotus*), and hitch (*Lavinia exilicauda*). If confirmed with diagnostic elements, this would document the presence of the extinct thicktail chub and rare splittail in Alameda Creek along with Sacramento perch.

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# USE OF AN ARTIFICIAL SUBSTRATE TO COLLECT WHITE STURGEON EGGS[1]

The white sturgeon, *Acipenser transmontanus*, is an important recreational and commercial fish in the Columbia River, Oregon and Washington. In 1988, the estimated recreational and commercial harvests of this species downstream from Bonneville Dam (the lowermost dam on the Columbia River, River Kilometer 234) were 43,100 and 6,900 sturgeon, respectively (Hess and King 1989).

Despite the economic importance of white sturgeon, there are relatively little data on its early life history in the Columbia River. Accordingly, a study was initiated in 1987 to better describe where and when white sturgeon spawn downstream from Bonneville Dam. Early in this study white sturgeon eggs were collected with plankton nets and bottom trawls (McCabe and McConnell 1988). In 1988, an egg collection system utilizing an artificial substrate was developed to sample the highly adhesive eggs of this species. This paper describes the fabrication and use of this artificial substrate system.

The collection system was constructed by cutting a roll of latex-coated animal hair (AK725R-4, manufactured by Air Kontrol, Batesville, Mississippi[2]) into 76 X 91-cm pieces and securing two back to back pieces to an angle-iron frame with strips of flat iron bar (Fig. 1). The strips of flat bar were held in place with nuts and bolts to facilitate removal of the substrate from the frame. Also, two strips of flat bar were welded in place across one side of the frame to provide additional support for the substrate. By placing the substrate pieces back to back in each frame, it made no difference which side of the frame rested on the river bottom. Two short sections (1.2 m) of 5-mm diameter cable were used to attach the frame to an anchor.

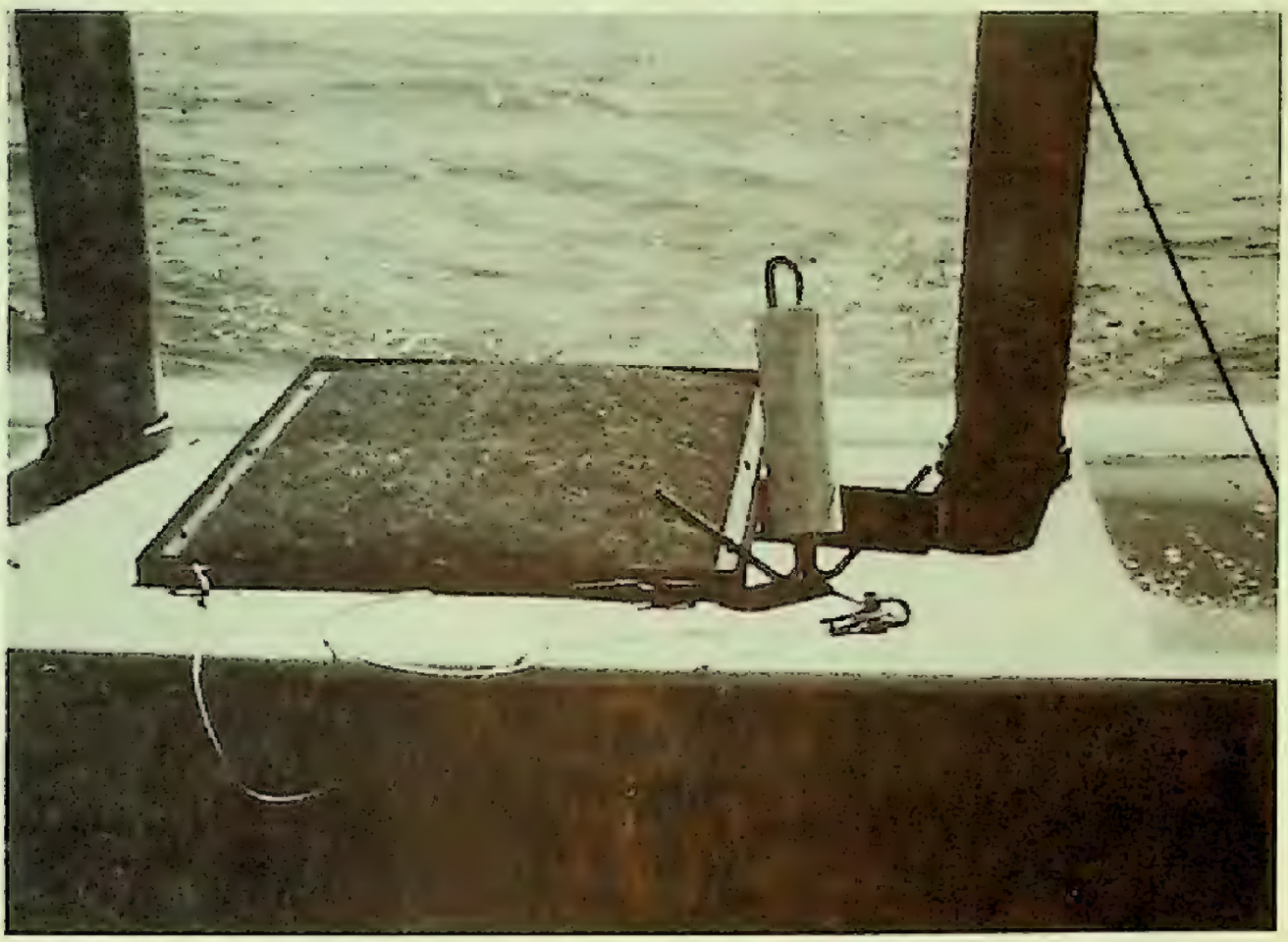
A three-fluke anchor similar to a grapnel was used to hold the substrate and frame in place on the river bottom, and proved successful in holding against strong currents on cobble-boulder bottoms. The anchor was constructed of a 30-cm section of PVC pipe (8-cm inside diameter), reinforcing steel bars (13-mm diameter), and concrete (Fig. 1). One piece of reinforcing bar was bent to form two of the anchor flukes (each fluke was about 20 cm long) and a loop for an attachment for the cables. A short piece of reinforcing bar was bent to form the third fluke and welded to the other reinforcing bar. The reinforcing bars were placed inside the PVC pipe and held in place with concrete. Total weight of the anchor was about 5.4 kg.

A buoy line (8-mm diameter) was attached to the anchor to mark the location of the substrate. Length of the line varied depending upon water depth and velocity. Artificial substrate systems were placed at depths ranging from about

[1] Accepted for publication October 1990.

[2] Reference to trade names does not imply endorsement by NMFS or NOAA.

FIGURE 1. The artificial substrate, frame, and anchor used to collect white sturgeon eggs in the Columbia River downstream from Bonneville Dam.



3 to 15 m and surface water velocities ranging from less than 1 m/s to greater than 2 m/s. In areas where surface water velocity was greater than 1.5 m/s, the length of the buoy line was at least four times the water depth. Depending upon water velocity, three to six buoys (30-cm long and 12-cm diameter) were secured to one end of the line; more buoys were required in swift water.

In 1988 and 1989, 685 and 305 white sturgeon eggs were collected on artificial substrates deployed downstream from Bonneville Dam, respectively. Individual collections ranged from 0 to 423 eggs in 1988 and from 0 to 212 eggs in 1989. At least one egg was collected on 10 out of 22 sets in 1988 and on 7 out of 24 sets in 1989. Eggs were removed from the artificial substrate directly by hand or with the aid of a pointed instrument such as a net-mending needle. When large numbers of eggs were collected, after hand-picking, the substrate was washed with water to remove eggs that remained entangled. Eggs were preserved in a 4% or greater buffered formaldehyde solution for later estimation of developmental stages and spawning dates.

The artificial substrate is a useful tool for identifying white sturgeon spawning areas and determining timing of spawning. Ideally, both a plankton net (Kohlhorst 1976, McCabe et al. 1989) and artificial substrates should be used.

Compared to the use of a net only, artificial substrates increase the chance of detecting spawning in an area because they can be fished for extended periods. In addition, artificial substrates can be placed in areas where it may not be safe or practical to use plankton nets. For example, if artificial substrates had not been used near the spillways at Bonneville Dam, we would not have detected spawning there. Disadvantages of the artificial substrate system are its vulnerability to theft and potential for the buoy line to become entangled in the propellers of passing vessels.

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